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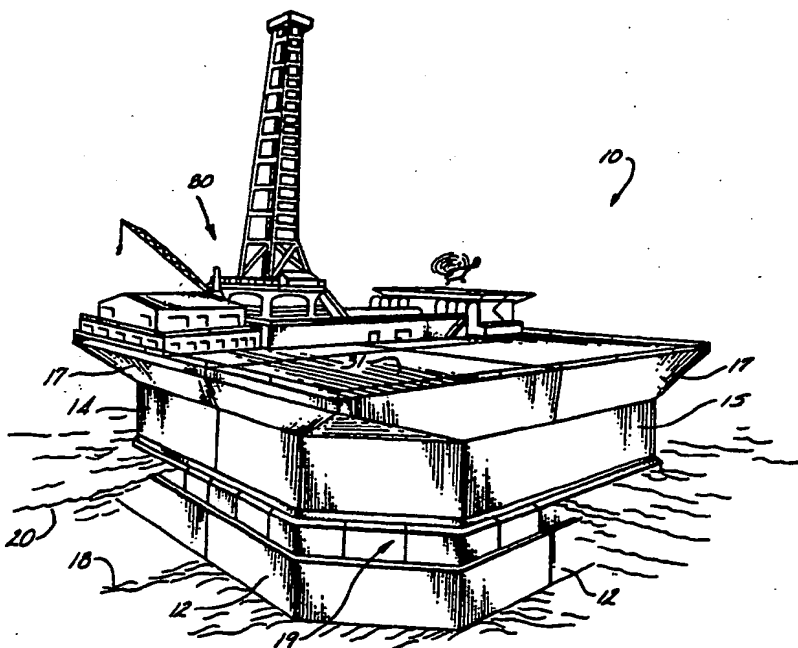
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(54) Title: MODULAR ISLAND DRILLING SYSTEM

(57) Abstract

A gravity-type offshore structure (10), useful as an offshore drilling platform, e.g., is provided for use in ice-covered waters such as offshore of the Alaskan and Canadian North Slope. The structure (10) is composed of a plurality of floatable and controllably ballastable modules (12, 14, 15, 17) each which can be fully submerged. The modules (12, 14, 15, 17) are stackable by selective ballasting and deballasting operations in a suitable sequence to define a mobile offshore structure (10). The structure (10) is assemblable adjacent a site of use and is floatable after assembly to, from and between successive sites of use. At each site of use the assembled structure (10) is ballasted by sea water to be supported by the sea floor (18) and to have sufficient deadweight, in combination with its support by the sea floor (18), to stand against ice loads urging the structure (10) laterally of the site. Major ones (14, 15) of the modules (12, 14, 15, 17) preferably are constructed of reinforced concrete arranged within the modules (14, 15) in honeycomb cellular fashion. A reinforced concrete armor belt (19) is removably installed around the structure (10) at its on-site load waterline. The structure (10) is useful in a range of water depths. The armor belt (19) is mountable to the structure (10) at a number of different elevations on the structure (10) to suit differing on-site load waterline locations. Individual modules (12, 14, 15, 17) can be used with other modules of the same or different size in a series of offshore structures individually useful in a characteristic range of water depths.



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MODULAR ISLAND DRILLING SYSTEMCross-Reference to Related Applications

15 This application is a continuation-in-part of application Serial No. 06/325,778 filed November 30, 1981.

Background of the InventionField of the Invention

20 This invention pertains to structural and procedural aspects of offshore platforms useful in Arctic waters on a year-round basis. More particularly, it pertains to a gravity-type offshore platform structure having modular components readily assemblable in Arctic waters and preferably comprised principally of large floatable and ballastable reinforced concrete elements of honeycomb-type internal construction, which elements are assemblable by novel procedures to provide a range of particular platform structures each suited for particular sites of use within a wide range of water depths.

Review of the Prior Art and the Need Presented

30 The seas, bays and inlets on the margins of the Arctic Ocean, outside the realm of the permanent North Polar icepack, present especially difficult problems to those desiring to explore for and to develop the oil and gas reserves which are suspected and known to exist below these waters. These waters are often very shallow; in many areas

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1 100 foot water depths are found 25 miles offshore. These
waters are remote from major centers of industry and
commerce. They are covered by sheet ice through November
to May and by floe ice in June through August, in a typical
5 year. Temperature variations are extreme.

Offshore drilling and production platforms useful in
waters of these depths have been developed for use in less
hostile environments. The factors noted above, in combina-
tion, mean that existing platform structures either cannot
10 be used at all in the Arctic, or they can be used only for
short periods annually when waters are free of ice. Exist-
ing platforms, if used, must either be moved into, used,
and moved out of the area from remote locations between
May and November, or they must be stored during ice periods
15 in protected local harbors which, because natural harbors
are virtually nonexistent, must be constructed at great
cost. For these reasons, existing offshore platforms of
conventional design have not been and are not likely to
be used in the Arctic.

20 In recognition of the special problems posed by the
Arctic environment, various innovative approaches to off-
shore operations have been proposed or implemented. Those
approaches proposed include the use of a suitable platform
and rig structure in a floating state during Arctic open
25 water periods, use of the same structure on land during
periods of ice formation and breakup, and use of the same
rig on an ice sheet (without allowance for ice movement)
during periods when the ice is of sufficient strength to
support the structure; see U.S. Patent 3,664,437. Other
30 proposals seek to adapt platforms designed for warmer
waters to Arctic conditions by the use of ice cutters and
the like to the pylon of a monopod structure or the legs
of a jack-up structure; see, for example, U.S. Patents
3,669,052, 3,693,360 and 3,696,624. Still other proposals
35 involve the use of massive moored floating platforms of



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1 conical or bell-like shape capable of being heaved buoyantly
to break and stand against encroaching ice. Yet another
proposal involves a massive unitary fixed platform having
a conical or hourglass configuration at and adjacent its
5 waterline for causing encroaching ice to ride up on the
structure and so break; see U.S. Patent 3,972,199. Other
proposals involve combinations and variations of the de-
scribed proposals.

To date, none of the proposals reviewed above has
10 been adopted in support of offshore operations in the
Arctic. The reasons are varied. In some cases, the
proposals are not suited to the shallow waters of interest.
In other cases, the costs of construction, placement and
operation of the proposed structures are unattractive.
15 In some cases, the proposed structures are not suffi-
ciently adaptable to varying sites of use to warrant the
requisite investment.

The innovation which has been adopted to date in
support of offshore Arctic operations is the artificial
20 island. Artificial islands are constructed in shallow
water from rock, gravel and sand to provide an operations
site capable of standing against extreme local environ-
mental forces, notably those due to moving sheet or floe
ice. While satisfactory and economically feasible in some
25 circumstances, artificial islands have practical limitations
on their utility. They are not movable. They are costly
to construct; construction costs rise sharply with increas-
ing water depth. Gravel and rock are not naturally readily
available in many areas of interest; ready availability of
30 adequate supplies of these materials directly affects the
cost of constructing an artificial island. Proposals to
overcome these limitations of artificial islands by the
use of man-made year-round ice islands have their own
limitations and have not been adopted.

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1 It is thus seen that a need exists for a structural
and procedural system which provides an Arctic offshore
operations platform, such as an oil or gas drilling or
5 production platform. Such a platform should be versatile,
i.e., capable of use directly, or without substantial or
costly modification, in waters of various depths. The
platform should be readily movable to enable it to be used
in different places over its useful life which should be
10 long. The system should be adaptable to varying sea floor
soils and soil conditions with minimal dredging or other
preparation of the sea floor site. The platform must be
capable of use year-round in the face of forces, notably
ice-generated forces, tending to move the platform from
15 its site of use. The platform should be capable of being
readily and economically fabricated in existing construc-
tion facilities remote from the Arctic, and moved effec-
tively and efficiently, without undue hazard, to Arctic
waters where it can be readily installed without reliance
20 on costly special equipment or procedures. The materials
used in constructing the platform should be readily avail-
able, of reasonable cost, and compatible with the hostile
Arctic environment. The basic platform structure also
should be compatible with a wide range of superstructure
25 arrangements, thus enabling the platform to be used by
different owners and operators who have their own pref-
erences for functional equipment sets and layouts, and to
be used for differing purposes such as exploration drilling,
production drilling, and production from completed produc-
30 tion wells, among other purposes. Further, the platform
structure and its method of installation must be compatible
with and protective of indigenous marine life and related
environmental standards which are stringent in the Arctic.

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1 Summary of the Invention

 This invention addresses the need identified above
in a manner which meets the diverse practical, economic,
functional, and environmental criteria and considerations
5 which have been noted among others relevant. The present
invention provides novel structural arrangements and pro-
cedural sequences which safely, efficiently, effectively
and economically comport with the many competing, and
often seemingly unreconcilable, factors pertinent to indus-
10 trial operations and facilities in the Arctic and other
areas of extreme conditions.

 Briefly stated, in structural terms, the invention
resides in a movable offshore structure of the gravity
type. The structure is movable buoyantly to and from
15 a site of use on a sea floor, the site being located in
waters in a selected range of water depths. The structure,
when installed at the site, extends from a lower end
located substantially at the sea floor through and above
the water surface to an upper operations end which is
20 adapted to carry a selected operations facility. The
structure has substantially flat and substantially verti-
cal walls throughout a portion of its height between its
lower end and a location a selected distance above the
water surface. In such portion of its height, the struc-
25 ture is comprised of at least one base unit. Each base
unit is floatable. The base units are reversibly ballas-
table with sea water adequately to impart to such portion
of the structure sufficient negative buoyancy, in combina-
tion with the surface engaged by the lower end of the
30 structure, to maintain the structure at a desired position
at the site under environmental forces applied horizontally
to the structure.

 In the presently preferred embodiment of the invention,
each base unit is fabricated of reinforced concrete arranged

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1 within the unit to define a plurality of vertical cells and
intercell webs.

More preferably, the structural composition of the
structure is such that it is comprised of one or more
5 tiers of modular structural units which are structurally
interrelated and equipped to cause the structure to have
a desired geometry and a desired suitability for an in-
tended purpose consistent with the environment at the
site. The modular units include at least one of the base
10 units which has selected height. Means cooperate between
the units in each tier and in adjacent tiers for securing
the units from lateral relative movement in response to
environmental forces. Each unit has a buoyant state.
Ballast means are operable for controllably ballasting
15 each unit between its buoyant state and a state of reduced
buoyancy which preferably is a state of substantial nega-
tive buoyancy. The several units are assemblable into the
structure by selective ballasting, deballasting and mating
of the units in a predetermined sequence. The several
20 units, when assembled, are floatable as an entity into and
out of partially submerged forceful engagement with a sea
floor in waters within the selected range of depths.

Organizationally, the offshore structure preferably
is provided as a kit of components having interrelated
25 and coordinated features and dimensions. The kit includes
a plurality of base units of standardized horizontal dimen-
sion but of differing heights, standardized deck storage
barges which may or may not carry the desired operations
facility as a part of their outfitting, a plurality of
30 armor panels which are mountable to the base units at
desired vertical positions on the base units, and, where
required, a spread base assembly upon which the pertinent
base units can be landed at the site. Suitable accessories
are provided for interconnecting the base units in a parti-
35 cular structure.



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1 Description of the Drawings

 The above-mentioned and other features and characteristics of this invention are more fully set forth in the following detailed description of a presently preferred
5 and other forms of structural and procedural embodiments of the invention. The following description is presented with reference to the accompanying drawings wherein:

 FIG. 1 is a perspective view of an offshore structure of this invention outfitted as an offshore drilling platform;

10 FIG. 2 is a chart showing the various major elements of the kit of components provided by the invention and assemblable into an offshore structure such as that shown in FIG. 1;

15 FIG. 3 is an exploded perspective view showing the relation of the major structural components of the offshore structure shown in FIG. 1;

 FIG. 4 is a cross-sectional plan view of one of the upper base units of the structure shown in FIG. 1, a cross-sectional plan view of one of the lower base units
20 of such structure being similar to the content of FIG. 4;

 FIG. 5 is a group of plan views of the lower and base units, and of the deck storage barges comprising the structure of FIG. 1, and which shows the vertical relation of access and other features;

25 FIGS. 6, 7, and 8 are simplified illustrations depicting steps in the interconnection between base units in a common tier of the offshore structure shown in FIG. 1;

 FIG. 9 is a cross-sectional elevation view of a bolted connection between adjacent base units in a tier
30 of the structure shown in FIG. 1;

 FIGS. 10 through 19 are simplified elevation views showing sequential stages of a procedure for assembling and installing the structure of FIG. 1;

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1 FIG. 20 is an enlarged fragmentary cross-sectional elevation view of the interface between vertically stacked base units at a positioning station between the units in the structure shown in FIG. 1;

5 FIG. 21 is a fragmentary cross-sectional elevation view through a moonpool of the structure of FIG. 1 showing an aspect of the base unit ballasting apparatus;

 FIG. 22 is a view similar to FIG. 21 showing another aspect of the base unit ballasting apparatus;

10 FIG. 23 is an exploded fragmentary perspective view of a portion of one of the base units of an offshore structure of this invention and shows the internal structure of the unit;

15 FIG. 24 is an enlarged fragmentary cross-sectional elevation view of an upper portion of a base unit; FIG. 24 shows the use of soffits in the construction of the base unit;

20 FIG. 25 is a fragmentary bottom plan view of a portion of the bottom surface of a lower base unit in the structure shown in FIG. 1;

 FIG. 26 is a cross-section view taken along line 26-26 in FIG. 25;

25 FIG. 27 is an enlarged fragmentary cross-sectional elevation view of another form of seating arrangement between stacked base units in an offshore structure of this invention;

 FIG. 28 is a view similar to that of FIG. 27 showing another seating arrangement between stacked base units;

30 FIG. 29 is an elevation view of an ice armor panel for the offshore structure shown in FIG. 1;

 FIG. 30 is an enlarged elevation view of the shear pin and pin housing in the panel shown in FIG. 29;

 FIG. 31 is a cross-section view taken along line 31-31 in FIG. 30;

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1 FIG. 32 is a cross-sectional elevation view of the torque pin and pin housing in the panel in FIG. 29;

 FIG. 33 is a cross-section view taken along line 33-33 in FIG. 32;

5 FIG. 34 is a fragmentary cross-sectional elevation view of an armor panel tension anchor assembly;

 FIG. 35 is an elevation view, partially in cross-section, which shows an offshore structure generally like that shown in FIG. 1 used in combination with a sea floor cellar for wellhead equipment;

10 FIG. 36 is an elevation view illustrating the use of a common lower portion of a structure with different upper portions at a site to provide, in sequence, different offshore platforms for different purposes;

15 FIG. 37 is a perspective view, partially in section, showing a base unit useful to define the entirety of a tier in an offshore structure of this invention; and

 FIG. 38 is a fragmentary, cross-sectional plan view of a valve and manifold chamber in a base unit, for example, showing aspects of the unit ballasting apparatus not shown in FIGS. 21 and 22.

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1 Description of the Illustrated Embodiments

 The presently preferred embodiment of this invention,
and the mode of practicing this invention presently consi-
dered to be the best mode, involves the use of reinforced
5 concrete to define the modular base units described here-
inafter. Many of the features and benefits of this inven-
tion, however, are not dependent on the use of reinforced
concrete base units. For purposes of explanation, and in
compliance with applicable statutes, the invention is
10 described herein, and depicted in the drawings, with refer-
ence to the presently preferred embodiment and perceived
best mode which features reinforced concrete base units.
However, if desired, and there may be circumstances where
such could be desired, the base units may be fabricated of
15 steel. Except where the following description, or the
accompanying drawings, can reasonably be interpreted to
pertain only to reinforced concrete (for example, the
content of FIGS. 23 and 24 and the related text), the
following description and the drawings are to be read and
20 interpreted as being pertinent to the use of reinforced
concrete or steel in the structural aspects of this
invention.

 An offshore gravity-type structure 10 according to
the presently preferred practice of this invention is
25 shown in FIG. 1. The structure provides an operations
platform at a desired Arctic offshore site where operations
of a specified nature are to be performed. When assembled
and installed at the site as an operational entity, the
structure carries a suitable operations facility 80 suited
30 to the desired operations to be performed. Structure 10,
as illustrated in FIG. 1, is outfitted and equipped with
an operations facility which adapts the structure to be
an offshore drilling platform for use in drilling of either
exploratory or production oil and gas wells.

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1 FIGS. 1, 2 and 3 show that structure 10 is composed
of a plurality of principal components arranged in a
plurality of tiers to define the major aspects of the
overall structure. Thus, structure 10 has a lower tier 11
5 composed of two lower base units 12 which are essentially
identical as shown in FIG. 3. A central tier 13 is composed
of two substantially but not precisely identical base
units which are similar to lower base units 12. The struc-
ture has an upper tier 16 composed of two essentially
10 identical major structural deck units 17. Units 12, 14,
15 and 17 are cooperatively interrelated, designed and
dimensioned so that they collectively provide, upon mating
together, a massive gravity-type structure having suffi-
15 cient on-board water ballast mass that the structure force-
fully engages a sea floor 18 at the intended site suffi-
ciently to stand against environmental forces during long-
term usage of the structure at the site in the Arctic.

The principal environmental forces of concern are ice
forces applied laterally to the structure in a manner
20 tending to move the structure away from its intended site.
Forces which act in a manner tending to crush the structure
are also of concern. An armor belt 19, composed of indivi-
dual armor panels, is installed circumferentially of the
structure at its mean waterline so that the belt extends a
25 selected distance above and a greater selected distance
below water surface 20. The armor belt is provided so
that base units 12, 14 and 15 can be constructed with
minimum material, while affording the overall structure 10
sufficient local strength in way of an adjacent ice sheet
30 to withstand potential damage from applied ice forces.

The overall planform configuration of structure 10,
especially through its central and lower tiers, is of a
rectangular nature, preferably square, with chamfered
corners. Since each of the tiers of structure 10 is
35 defined by a pair of principal structural components of



1 the structure, each of the components in a tier is of rectangular plan configuration, as shown in FIGS. 1 and 3.

5 In the presently preferred embodiment 10 of this invention illustrated in FIG. 1, each of base units 12, 14 and 15 are 234 feet long and 116 feet wide. The corners of these units are chamfered, i.e., relieved, by 42 feet 4 inches along the length and width of the respective base unit. Lower base units 12 are 44 feet high, whereas central base units 14 and 15 are 32 feet high.

10 FIG. 3 shows that the rectangular units in each of the substantially square tiers of structure 10 are turned at 90° to each other in terms of their length orientations in the respective tiers of the stack of components comprising structure 10.

15 FIG. 2 is a chart which shows that an offshore structure according to this invention can be defined to suit particular conditions of water depth, ice load and other environmental forces, and subsea soil conditions, among other pertinent factors, by appropriate selection of suitable components from an inventory of component parts. The inventory of component parts, in effect, provides a kit from which a particular offshore structure can be built initially or subsequently modified for use at another site. Constituents of the kit of components available and usable to define the upper tier of the structure include a simple, essentially rectilinearly configured deck storage barge 21 denoted DSB in FIG. 2, a deck storage barge with reserve storage capacity (provided by the addition of side sponsons to a DSBR) denoted DSBR in FIG. 2, and an integrated drilling unit (IDU) 22 which is essentially a DSBR outfitted prior to arrival at the intended site of use with super-structure and other equipment adapting the DSBR to the intended function of drilling of offshore subsea oil and gas wells. While not shown, another form of upper tier component would be a DSBR prefitted as a production facility

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1 for producing oil and gas from completed production wells;
such a component would be an integrated production unit
(IPU). Other yard-outfitted upper tier components suited
5 for other operational uses are also within the scope of
this invention.

Also with reference to FIG. 2, the components used to
define the lower and central tiers, or only the lower tier
of an offshore structure according to this invention, if
appropriate, are referred to as "basic bricks", abbrevi-
10 ated BB in FIG. 2. The terms "basic brick" or merely
"brick" are often used in the following description to
refer to these components of a structure according to this
invention. It is a feature of this invention that the
bricks are preferably of honeycomb internal arrangement
15 and are preferably fabricated of reinforced concrete.
The bricks all have the same planform configuration and
dimensions but are available in varying heights such as 44
feet, 32 feet and 17 feet; 44 foot and 32 foot high bricks
are being used in tiers 11 and 13, respectively, of exem-
20 plary and presently preferred offshore structure 10.

The kit components useful to define armor belt 19 are
also preferably constructed of reinforced concrete. The
individual armor panels are of standardized height (12
feet in the preferred embodiment shown in FIG. 1), but are
25 provided in two standard widths of 28 and 14 feet, respec-
tively. In FIG. 2, these armor panels are designated as
components AP28 and AP14, respectively.

FIG. 2 also illustrates the components available for
definition of an offshore structure according to this
30 invention which can, if desired, include an integrated mud
base 25 denoted IMB. An IMB may or may not be used in an
offshore structure depending upon the nature of the sea
floor soils at the intended site of use. The ability of
structure 10 to stand against expected ice sheet loads is
35 a function of the mass of the structure as installed at



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1 the intended site and the effective coefficient of friction
between the structure and the sea floor soil. In those
instances where the sea floor soil has sufficient cohesion
and integrity to be able to directly support the fully
5 ballasted offshore structure without the use of an inte-
grated mud base, then no such base would be used, and the
bricks defining the lowermost tier of the structure would
be landed directly upon the sea floor. In other locations,
however, the sea floor soil may be inadequately consolidated,
10 or otherwise inadequate, in combination with the mass of
the fully ballasted offshore structure, to either directly
receive the offshore structure or to provide the desired
coefficient of friction to enable the structure to stand
against expected ice loads, or both. In such circumstances,
15 an IMB is used to distribute and spread the mass of the
offshore structure, as shown in FIG. 1, over an extended
area of the sea floor soil. An IMB, if used, is constructed
of steel, preferably, and includes a lower, substantially
annular depending skirt portion 26 configured to penetrate
20 into the adjacent sea floor soil, and a structural mat
portion 27 of suitable horizontal and vertical dimensions
(in the range of 10 to 25 feet high) selected with reference
to the specific soil engineering problem presented at the
site and for which the individual IMB is designed. The
25 outer walls of the mat portion of the IMB slope upwardly
and inwardly. Suitable chocks or other keying projections
28 extend upwardly from the upper surface 29 of the IMB
mat portion 27 to engage the side walls of the lowermost
basic bricks of the pertinent offshore structure.

30 Thus, FIG. 2 illustrates an important feature of this
invention, namely, that the principal structural components
of an offshore platform according to this invention are of
standardized dimension and functional arrangement, and are
provided as functional modules which, by judicious selection,
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1 can be assembled to provide an offshore structure specifi-
cally suited to the water depth, environmental force, sea
floor conditions, and other factors pertinent to a particular
site and a particular operation of interest. The only
5 nonstandard substantial component of an offshore structure
according to this invention is the optional integrated mud
base which is, in essence, customized to particular soil
engineering considerations at a particular site.

As noted above, the exemplary offshore structure
10 shown in FIG. 1 is outfitted as a production offshore
drilling platform. It is usual that from such a platform
a number of wells are drilled from which oil and/or gas
will be produced. Accordingly, in order that structure
10 can have maximum flexibility and utility when used as
15 an offshore production drilling platform, its principal
structural components are arranged to define a pair of
moonpools, i.e., passages which extend vertically through
the structure from its upper deck 31 to its lower surface
as defined by the bottom surfaces of the lowermost tier of
20 bricks used in the offshore structure. In the exemplary
structure shown in FIGS. 1 and 3, for example, the moon-
pools are 28 feet square, and are defined by vertical
passages 33 through the bricks in the structure. There is
one passage 33 through each of bricks 12, two such passages
25 through brick 14, but none through brick 15 - see FIG. 3.
Similarly, vertical passages 34 of the same dimensions as
passages 33 are defined through each of DSBR units 17, as
shown in FIGS. 3 and 5. Upon stacking of the deck units
and bricks in a given offshore structure, passages 33 and
30 34 are aligned along common axes to define the desired
moonpool features.

FIG. 4 is a cross-sectional plan view of base unit
14, the internal construction of which preferably is of
the honeycomb type; as noted above, the base unit bricks
35 are preferably fabricated essentially entirely of reinforced



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1 concrete. The honeycomb construction of each brick results
in a unit which is very strong, while also being light.
As shown in FIG. 4, the internal structure of base unit 14
(to which all bricks are similar) is predominantly defined
5 in accordance with the teachings of U.S. Patent 3,833,035
in that it is comprised of a plurality of regularly spaced
circularly cylindrical vertical cells 35 which are inter-
connected in orthogonal directions by intercell webs 36
10 which cooperate to define further cruciform cells 37 within
the base unit. Each base unit has opposite parallel,
flat, vertical end walls 38, and vertical, flat major and
minor side walls 39 and 40. Major side wall 39 extends
continuously between the base unit end walls, whereas the
15 minor side wall 40 is connected to the unit end walls via
vertical and substantially flat corner walls 41 which lie
at angles of 45° to the adjacent end and side walls.

The end, minor side, and corner walls of a base unit
will be exposed in use to environmental forces, notably
ice forces. To enhance the ability of the base units to
20 resist applied ice loads, and to distribute such applied
ice loads into the remaining structure of the base unit,
the interior structure of each base unit immediately
adjacent to walls 38, 40 and 41 is defined by a plurality
of vertical parallel shear walls 42 which extend from the
25 inner surfaces of the adjacent outer walls to vertical
bulkhead walls 43. Bulkhead walls 43 are located approxi-
mately 19 feet inboard from the adjacent outer walls of
the base unit; the remaining major portion of the interior
volume of each base unit is defined by the combination of
30 circular cells 35 and intercell webs 36. The entirety of
the interior of each base unit is of a generally honeycomb
structural arrangement.

Circular vertical cells 35 preferably are 10 feet in
diameter and are spaced on 14 feet centers longitudinally

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1 and transversely of the base unit. Shear walls 42 preferably
bly are located on 4 foot 8 inch centers. Interior water-
tight partitions within each base unit are provided by
5 bulkheads 43 and by additional bulkheads 44, shown in FIG.
4, which are arranged to define nine watertight compartments.
The other bricks and the deck barge units are similarly
internally compartmented which serve as ballast spaces.

Ballast pumps, manifolds, and control valves are
located within a manifold chamber 45 defined within each
10 base unit 12, 14 and 15, as shown in FIG. 5. Each manifold
chamber is connected to the ballast chambers of the corre-
sponding base unit by suitable piping within the base
unit. As shown in FIG. 5, the manifold chambers 45
15 are located in the several base units in such manner that
when the base units are stacked, the various manifold
chambers are accessible either from the top (as in the
case of base unit 14 via a suitable hatch 46 provided in
the bottom of one of deck units 17) or via the moonpool of
the pertinent base unit. Access from a moonpool passage
20 into a manifold chamber is provided by a double-entry
bolted hatch assembly mounted in the common wall between
each moonpool passage 33 and the adjacent manifold chamber.
Each of the ballast chambers within each base unit is
accessible from that base unit's manifold chamber via a
25 network of catwalks 47 (see FIG. 4) which are installed
through and into various ballast chambers. Access from
the manifold chamber to the catwalk network is provided
by suitable double-entry bolted hatches.

Appropriate openings are provided through the non-
30 watertight shear walls and bulkheads of each base unit
for purposes of flow of water and air between the cells
of the base unit, and to provide access via the catwalks
for personnel. The catwalks are located in the upper
portions of each base unit.

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1 Each deck storage barge 17 is also equipped with ballast pumps, manifolds, valves and piping.

5 As shown in FIG. 5 with reference to bottom base units 12, a ballast suction duct 47 communicates in each base unit from the moonpool duct passage to the exterior of the base unit. Also, one of the circular cells in each base unit which is incapable of being used as a bottom tier base unit is defined as an inlet sump 48 which has communication to the exterior of the base unit by a suitable duct 49 extending 10 between the ballast sump and an outer wall of the unit. As a practical matter, every base unit provided in the kit illustrated in FIG. 2 is capable of being used as a bottom base unit. Therefore, every base unit which has a moonpool passage 33 vertically through it is equipped with a lateral suction duct 47 for use in ballasting the base unit, particularly after the base unit has been engaged with the sea floor or the upper surface of another base unit. 15

20 To facilitate assembly and installation of offshore structure 10 at an Arctic location, as well as to simplify the logistics of transporting the structure components from remote sites of fabrication, the deck units of the offshore structure are designed as submersible barges capable of transporting the heaviest base units in the system, i.e., base units 12 (BB44 units). This is the case 25 whether the deck units are of the simple DSB type (item 21 in FIG. 2) or the greater capacity DSBR units (item 17 in FIG. 2).

30 From the description of the invention to this point, it will be appreciated that the major components of an offshore structure according to this invention are quite large. There are no facilities presently existing, or likely in the near future to exist, in the Arctic suitable for construction of these components. The components must necessarily be built in existing shipyards or other suitable 35 construction facilities, all of which are located in



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1 temperate and tropic areas. It will also be appreciated
that each tier of the offshore structure could be defined
as a unitary component (see FIG. 37) rather than as a pair
of components; such a component would be very large and
5 would weigh, dry, as much as 30,000 tons or more; facilities
for the fabrication of such a large reinforced concrete
construction do not presently exist adjacent suitable
waterways, with only several possible exceptions.

Accordingly, while the inventive scope of this invention
10 extends to an offshore structure having single component
tiers, it is presently preferred that the tiers of an
offshore structure according to this invention be defined
by two or more components in order that the components can
be manufactured in a much larger number of shipyards and
15 similar facilities which exist worldwide, including in the
United States and Canada. Following construction remote
from the Arctic, the components are towed to an assembly
location selected as closely adjacent to the site of intended
use as possible. The design and construction of
20 deck units 17 or 21 as transport barges for the base units
contribute to the economy and efficiency of the present
invention. Construction of both the base unit bricks and
the DSBs or DSBRs can be accomplished in most areas of the
Pacific perimeter. Since the width of each unit is only
25 116 feet and the maximum light ship weight is 16,000 tons,
the major modular components of the offshore structure can
be competitively bid by a large number of shipyards and
construction sites in this area. Both the width and draft
of the individual base unit bricks are such that the necessary
30 tows can be easily integrated into the normal sealift
of personnel and materiel to the United States and Canadian
Arctic North Slope.

Deck units 17 or 21, considered as submersible barges,
are so defined that one of the most massive of the bricks,
35 which has a dry weight of approximately 16,000 short tons,



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1 can be loaded aboard a corresponding barge to be towed dry
to an Arctic assembly location adjacent the intended site
of use. The lighter base units, such as the BB32 units
5 which weigh approximately 11,000 short tons, or the even
lighter BB17 units, can be transported to the Arctic North
Slope area on available commercial submersible barges. As
the base units are loaded aboard the respective submer-
sible barges, all ancillary hardware useful in the base
unit mating procedure will also be installed or loaded.

10 The generalized procedure for stacking the base and
deck units of offshore structure 10 is shown, in sequence,
in FIGS. 10 through 19, and certain procedures preliminary
to the stage of operations illustrated in FIG. 10 are
shown generally in FIGS. 6, 7 and 8.

15 During the construction of base units 12, for example,
certain features are defined in them along their major
side surfaces 39 to facilitate their mating and inter-
connection. These features include at least a pair of
mating pin 52 and socket 53 features at spaced locations
20 along the base unit major sides; see FIG. 8. All of pins
52 may be defined in one of the base units, and all of
the sockets 53 may be defined in the other of the base
units, but it is preferred, in order that each base unit of
a given size can be interchangeably matable with any one
25 of a number of other base units of the same nominal
size, that the pins and sockets be defined by both of the
interconnected base units. The pins and sockets co-act
with each other, in the manner shown in FIG. 8, to secure
the mated base units from relative motion toward each
30 other horizontally, from longitudinal relative motion,
from relative motion vertically, and from angular motion
about a horizontal axis perpendicular to the base unit
major side walls. Also, at spaced locations along the
length of each base unit adjacent its top 54 and bottom 55
35 surfaces, the base units define cooperating bumper stop



1 projections 56. The bumper stop projections abut each
other upon mating of two like or substantially like base
units to limit angular motion between the base units about
horizontal and vertical axes disposed parallel to side
5 surfaces 39. Where, as preferred, the base units are
fabricated of reinforced concrete, bumper stop projections
56 are formed as a part of the concrete casting fabrication
process pertinent to each base unit; pins 52 and sockets
53 may also be formed of concrete or they may be steel
10 fixtures applied to the base units after the concrete
casting phase or other pertinent portion of the fabrication
process has been completed. Features 52, 53 and 56 are
proportioned so that, when they are mated and abutted, a
space about two feet wide is provided between walls 39 of
15 the adjacent base units; this space is adequate for access
between the base units during interconnection of the units.

At the location where the base and deck units are
constructed, each completed base unit 12, for example,
is disposed on the upper surface of a corresponding barge
20 DSB or DSBR in such a manner that, as shown in FIGS. 6-8,
the major side surfaces 39 of the base units are disposed
outboard of the adjacent sides of the barge by, say, one
or two feet. This is done to provide access, during the
process of mating and interconnecting the base units, to
25 the base unit interconnection assemblies 60 (shown in FIG.
9) located along the bottoms of the base units; access is
inherently available to the interconnection assemblies at
the upper portion of the interface between horizontally
adjacent base units.

30 Similarly, as shown in FIGS. 6 and 7, the deck unit
barges also include cooperating aligning and mating features
along the sides which are overhung by the major sides of
the base units. Thus, as shown in FIG. 6, a pair of mating
guide cones 58 are carried by one of barges 17 at selected
35 locations along its length, preferably adjacent the ends



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1 of the base unit, while the other barge is fitted with
cooperating guide cone sockets 59. Cones 58 and sockets
59 preferably are securely, yet releasably, affixable to
5 the respective barges. They are first installed on the
barges at the base and barge fabrication site for purposes
of preliminary alignment and mating of the base units for
the purposes which are described below. Thereafter, they
are removed for transit of the loaded barges to the loca-
10 tion of assembly of offshore structure 10. At such loca-
tion, they are temporarily reconnected to the barges to
serve their intended functions during the final base unit
mating and interconnection process.

As represented in FIG. 8, a plurality of horizontal
bolted connection assemblies 60 are provided at spaced loca-
15 tions along the interface between the base units in a given
tier of offshore structure 10 at or adjacent both the
upper and lower extents of the interface. If desired,
vertically disposed bolted connection assemblies, similar
to assemblies 60, also may be provided between cooperating
20 base units at or near the opposite ends of the interconnec-
tion interface. Details of a suitable interconnection
assembly 60 are shown in FIG. 9 with reference to a top
horizontal bolted interconnection assembly.

As shown in FIG. 9, in way of each bolted intercon-
25 nection assembly, the outer surface of each base unit major
side wall 39 is recessed, as at 61. Suitable bolting studs
62 are cast into or otherwise affixed to each of the base
units to project horizontally along carefully positioned
axes into and beyond the recesses. One of a pair of joint
30 weldments 63 is secured on each set of bolting studs by
nuts 64 and washers 65. Each joint weldment defines a
horizontal bolting flange 66 through which vertical bolting
holes 67 are defined at predetermined locations along the
pair of joint weldments 63. The flanges are disposed in
35 coplanar relation and are interconnected by top and bottom



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1 joining plates 68 which are drilled to define a plurality
of holes corresponding in number and pattern to the number
and pattern of holes 67 in the cooperating flanges 66.
The top and bottom joining plates and the bolting flanges
5 are interconnected by suitable nut and bolt sets 69, as
shown in FIG. 9.

At the location where the base units are initially
loaded upon their transport barges, e.g., deck unit barges
17, each interconnection assembly is fully made up in a
10 semi-tight condition in such manner that the joint weld-
ments 63 are disposed outwardly along studs 62 from recess
surfaces 61, thereby to define a gap between the respective
joint weldments and recess surfaces. These gaps are filled
15 with a hard-setting grout 70 which is allowed to hard set
before the interconnection assembly is partially disassem-
bled prior to transit of the base units to the site of
final mating and assembly. Thus, at the location where
the base units are prepared for transit to the final area
of use, each interconnection assembly is adjusted and
20 finally defined before disconnection of the assembly for
transit by removal of nuts and bolts 69 and top and bottom
joining plates 68. At this point, a given pair of base
units become an essentially matched set. It will be appre-
ciated, however, that any base unit of a given size can
25 be adapted for interconnection with any other base unit of
the same nominal size simply by disconnecting the joint
weldment 63 from that base unit and by chipping out grout
70 to ready the base unit for "customizing" into matched
set status with any other base unit.

30 After the several bolted interconnection assemblies
have been adjusted and temporarily disconnected, the mating
guide cone 58 and socket 59 fittings for the corre-
sponding deck unit barges are removed, as by unbolting,
and suitably stored aboard the barges for transit. The
35 barges, each with a base unit 12 disposed thereon, are



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1 then coupled via suitable towing bridles 72 to tugs 73 or
the like for towing to the Arctic site of intended use.
See FIG. 6.

5 Upon arrival of the base units at the Arctic site of
mating and assembly, the submersible barges re re-fitted
with their mating cone and socket units 58 and 59, as
shown in FIG. 7. One of the barges is moored in an essen-
tially fixed position by use of mooring lines 74 and suit-
able winches 75 as shown in FIG. 6. The two base units
10 and barges are then interconnected by suitable cables 76
and winches 77 so that the unmoored barge can be drawn,
under careful control, toward and into mating engagement
with the moored barge and its base unit. Precise positional
alignment and mating of the barges with each other is
15 accomplished via cones and sockets 58, 59, whereas similar
mating alignment of the deck units with each other is
assured by cooperation between pins 52 and sockets 53, and
by cooperation between bumper stops 56. Such mated align-
ment between the barges and base units is maintained by
20 keeping tension on cables 76 while bolted interconnection
assemblies 60 are reassembled. This, then, presents the
state of affairs which exists adjacent to the final site
of use of the offshore structure prior to the stage of
mating and assembly illustrated in FIG. 10.

25 As shown in FIG. 10, the final mating and assembly of
the major components of offshore structure 10 is carried
out adjacent to, but in waters deeper than, the final site
of use of the structure. After a pair of bottom base
units 12 have been mated and interconnected, the two sub-
mersible deck unit barges 17 are controllably ballasted to
30 become decreasingly buoyant, then neutrally buoyant, and
then slightly negatively buoyant, so that the deck unit
barges sink away from base units 12 to rest upon sea floor
79. In this manner, the interconnected bottom base units
35 12 are rendered free-floating in an essentially unballasted



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1 state. The free-floating bottom base units are then moved
from over the submerged barges to a location of temporary
anchorage. The barges are then refloated and moved to a
nearby location where they are mated and interconnected
5 according to a procedure similar to that described above.
The interconnected deck unit barges may then be outfitted
with the desired superstructure and deck equipment to
define the desired operations facility which, in the case
of offshore structure 10, is an exploration drilling
10 facility. The outfitting of the interconnected deck unit
barges preferably is carried out in parallel with the
interconnection of the two base units defining the central
tier 13 of base units of structure 10.

15 Either concurrently with or following completion of
the operation illustrated in FIG. 10, base units 14 are
moved to a suitable mating and interconnection location
on their submersible transport barges. Such base units
are interconnected generally in the manner described above.

20 FIG. 11 depicts tiers 11, 13 and 16 of offshore struc-
ture 10 free floating on the ocean surface as discrete
subcombinations of components of the desired ultimate
structure. FIGS. 12-16 show the steps in the final mating
and assembly of the various tiers of structure 10 into the
fully assembled structure at FIG. 10.

25 To commence the final mating and assembly of structure
10, central tier 13 is moved into waters having a depth
slightly in excess of the height of tier 13 and the light-
ship draft of tier 16 as outfitted with the basic structural
features of operations facility 80; in the instance where
30 the central tier is composed of BB32 units, a suitable
water depth is on the order of 37 feet. At such location,
the internal ballast systems of tier 13 are utilized to
controllably ballast the tier to a negatively buoyant
state to place it on the sea floor in a fully submerged
35 condition. The upper tier 16 is then floated into position



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1 over the submerged central tier, disposed in the proper
orientation relative to the central tier, and keyed into
position relative to the central tier, as by use of the
5 guide pin assemblies shown in FIG. 20. Then, the internal
ballasting systems of upper tier 16 are operated to sink
the upper tier into contact with the upper surface of the
central tier. The ballast state of the upper tier is
maintained as the central tier is unballasted to render
10 the combination of tiers positively buoyant so that such
combination can float free of the sea floor to the condi-
tion depicted in FIG. 13.

Once the combination of tiers 13 and 16 has floated
free of the sea floor, deballasting of tier 13 is continued
at least until the combination has risen sufficiently in
15 the water that deballasting of upper tier 16 can be com-
menced and pursued without risk of reducing the inter-tier
contact forces which are always relied upon to secure the
tiers together.

Next, lower tier 11 is moved into waters having a
20 depth in excess of the height of the sum of the lower tier
height and the pertinent draft of the combination of tiers
13 and 16. Where the lower tier is defined of BB42 base
units, a suitable water depth is on the order of 64 feet.
The lower tier is then rendered negatively buoyant in a
25 controlled manner and positioned on the sea floor as shown
in FIG. 8. Next, as shown in FIG. 9, the combination of
the central and upper tiers of structure 10, as previously
mated together, is floated into position over submerged
lower tier, disposed in the proper angular relation to the
30 lower tier, and controllably ballasted into proper mating
engagement with the lower tier. Again, in this mating
operation, pins 82 (see FIG. 20) are used. Once mating of
the lower tier with the combination of the central and
upper tiers has occurred, the lower tier is deballasted,

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1 with subsequent deballasting of the central and upper
tiers as needed, to cause the now essentially fully assem-
bled offshore structure 10 to float free of the sea floor.
At this point, the assembly will have a draft less than
5 the water depth at the site of intended use of the offshore
structure and the water depth along the path of movement
between the site at which the operations depicted in FIG.
9 have been performed and the intended site of use. The
fully assembled, but not yet finally installed offshore
10 structure is then floated, as shown in FIG. 11, to the
intended site of use where, as shown in FIG. 12, it is
ballasted into engagement with the sea floor. Thereafter,
all of the ballast spaces of the offshore structure are
filled, either fully or to the extent necessary, to cause
15 the landed offshore structure to achieve its design dead-
weight, thereby to produce the desired forceful engagement
of the landed structure with sea floor 18 adequately, in
combination with the coefficient of friction provided
between the structure and the sea floor soils, to enable
20 the offshore structure to stand against horizontal loads
applied to the structure by ice during the following ice
seasons over the period during which the offshore struc-
ture is in use at that site. After full ballasting of
the installed offshore structure, stores, supplies and
25 operational liquids, including all fuel, potable water,
and other materials required, are loaded aboard the off-
shore structure.

Offshore structure 10, as shown in FIG. 1, has been
designed, principally in the context of the deck units 17,
30 to provide sufficient storage capability, deck space and
capacity to support at least four months of operation on
site without major resupply.

Offshore structure 10 and its installation procedures
are designed so that the structure can be operational

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1 within 30 to 42 days after arrival of its major components
in the Arctic.

5 A plurality of positioning and shear pins 82, shown
in cross-section in FIG. 20, are installed between verti-
cally adjacent components of offshore structure 10 during
the course of mating and assembling the components accord-
ing to the procedure described above. The pins enable
precise alignment of vertically adjacent components, and
also provide substantial resistance to shear and lateral
10 relative motion between the components along the horizontal
interface 91 between them in the assembled structure. The
shear pins are disposed at selected locations in the compo-
nents in the central and upper tier components of struc-
ture 10 for registry in upwardly open sockets 83 disposed
15 at corresponding locations in the upper surfaces of the
bottom and central components. Pins 82 preferably are
provided in the form of heavy-wall steel pipes of, say, 30
inch diameter, and have pointed lower ends 84; if desired,
the pins can be solid. Pins 82 are carried in vertical
20 guide sleeves 85 which open downwardly through the lower
surface 55 of the component within which they are carried.
Sockets 83 and guide sleeves 85 preferably are fabricated
of steel pipe which has an inner diameter greater than the
outer diameter of pins 82 by an amount which is selected
25 consistent with the tolerances realistically capable of
observation in constructions having the size and nature
here pertinent. The sockets and guide sleeves are perma-
nent features of the respective components of structure
10; in the instance of the reinforced concrete base units,
30 the sockets and sleeves are cast into the upper and lower
portions of the base units, respectively. The base unit
sockets and guide sleeves have circumferential mounting
flanges 86 and 87 at their opposing ends, such flanges
being embedded in the concrete defining the lower 88 and
35 upper 89 slabs of the base units. Also, it is preferred



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1 that at least flanges 86, which lie within the thickness
of the adjacent slab, be securely connected to the steel
reinforcing bars (not shown in FIG. 20, but see FIG. 30,
for example) of the slab.

5 Prior to mating of a base or deck unit with another
base unit in final assembly of structure 10, pins 82 are
carried wholly within their corresponding guide sleeves.
At the time a component carrying pins 82 is positioned
above a component with which it is to be mated, the pins
10 are partially lowered to project a selected distance below
the bottom surface of the corresponding component. The
pins are secured in their guide sleeves in such partially
lowered positions in a suitable manner. The upper ends of
sleeves 85 are closed in the event that the sleeves do not
15 extend to the upper surface 54 of the component within
which the sleeves are carried. Closure of the upper ends
of sleeves 85, in the instance where the sleeves do not
extend to the upper surface of the pertinent component, is
desired so that the annulus between the exterior of each
20 pin and its guide sleeve does not provide a path for entry
of sea water into the component during the ballasting
procedures pertinent to mating of vertically adjacent com-
ponents in structure 10.

The projection of the lower ends of the guide pins
25 below the bottom surface of the corresponding deck or base
unit facilitates registry of the pin ends with the upper
ends of sockets 83 so that precise positioning, within
acceptable tolerances, of the components to be mated is
accomplished with ease and dispatch. If desired, a quan-
30 tity of sand 90 or similar material can be disposed in the
closed lower end of each socket 83 to provide for firm
seating of the pins in the sockets upon final lowering of
the pins after component mating has occurred.

FIGS. 21 and 22 are simplified cross-sectional eleva-
35 tion views showing the base units defining the lower and



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1 central tiers 11 and 13 mated together with the lower tier
base units resting on sea floor 18, and with the ballast
spaces of these base units fully or partially ballasted.
5 FIGS. 21 and 22 illustrate different stages in the proce-
dure for ballasting and deballasting the base units in the
course of initially mating and assembling structure 10 and
in placing the fully assembled structure at its intended
site of use. FIG. 21, for example, shows that, in each of
10 the ballastable components of structure 10, the manifold
and valve chamber includes a main ballast header manifold
94 in the lower part of the chamber. Each manifold 94 is
connected via ballast pipes 95 to each ballast space within
the component via a corresponding valve 96 located within
15 the lower portion of chamber 45 and operable, via a reach-
rod, from an upper portion of the chamber at the catwalk
level. Each header manifold has two valved connections 97,
98 (see FIG. 38) to the exterior of the component adjacent
its lower surface 54. Connections 97 and 98 are to the
20 moonpool passage of the component if the component is one
which has a moonpool passage.

While not shown in the accompanying drawings, it will
be appreciated that each ballast space in the ballastable
components of offshore structure 10 has an air vent con-
25 nection from its upper portion to the exterior of the
component. If the component defines a moonpool passage,
all ballast space vents are to the moonpool passage. Each
vent pipe terminates at a quick-disconnect "Kamlock" con-
connector fitting which is accessible from the exterior or
30 moonpool passage of the component. Suitable vent hoses,
equipped with corresponding connector fittings, are engage-
able with the vent termination fittings to provide commu-
nication from the vent pipe from each ballast space to
atmosphere even when the corresponding base unit is fully
35 submerged. In this way, each ballast space in the compo-
nents, especially in bottom base units 12, can be fully



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1 ballasted or deballasted even when fully submerged.

It will also be appreciated that, consistent with the use of water ballast in the several components of structure 10, and consistent with the focus of this invention upon
5 structures suitable for year-round offshore use in Arctic waters, the ballast spaces in the base and deck unit components of the structure are each equipped with heat exchangers which are elements of a ballast water heating system (not shown). In many, if not most uses of structure
10 10, the ballast spaces in its components will be fully filled with sea water ballast, thus affording no room for ballast water expansion due to freezing. The heating system also includes liquid phase heaters (preferably diesel fired), circulating pumps, system pressure sets and controls,
15 major aspects of which are located in the operations facility on the upper deck of the assembled and installed structure. Each ballast space in the base and deck units is equipped with a heating coil connected to the heaters and pumps via supply and return headers located in the manifold chamber
20 45 for the respective unit. A control panel is provided on which is displayed the temperature of water in each ballast space as measured by suitable sensors. A thermally controlled three-way valve with manual preset and ballast space temperature feedback serves to automatically maintain the desired water temperature in each ballast space. It is
25 presently preferred to use four independent, but cross-connectd, closed loop, pressurized fluid heating systems in the preferred structure; each independent heating system preferably includes a 2,500,000 BTU diesel fired heater for the circulating fluid. Selected portions of the inner
30 surfaces of the ballast spaces are insulated to reduce the energy required to maintain the ballast water at about 35° F during periods when the ballast water heating system is used.

35



1 The ballast and vent systems provided in the brick
components of structure 10 are sized to provide sinking
of a brick, or brick pair, in 9 to 12 hours by free flood-
ing and pumping. The ballast piping 95 to the ballast
5 spaces is sized to provide a uniform flooding rate in each
space. The actual flooding time required in any particular
situation will depend upon the particular flooding sequence
selected. The ballast and vent piping systems afford
controlled flooding and draining of the ballast spaces
10 within each base unit and in the deck units. The ballast
systems are required both when the base unit bricks are
grounded with the base unit top surface 55 above the water
surface, and also on those occasions when the base unit
bricks must be fully submerged. Accordingly, the ballast
15 systems are configured to enable fill and drain operations
to be performed without the need to enter watertight com-
partments or to operate system valves from the upper surface
of a base unit.

Portable electric submersible pumps 100, preferably
20 rated at about 4000 gpm and powered by portable electric
generators, are used to ballast and deballast the several
modules of the offshore structure. As shown in FIG. 38,
which is a fragmentary cross-sectional plan view of a base
unit manifold chamber 45, valves 97 and 98 are connectible
25 to the suction and discharge ports, respectively, of a sub-
mersible pump 100 via connections which each include a sea
valve 99. By this arrangement, the ballasting system for
each base and deck unit in structure 10 can be operated to
draw in or discharge ballast sea water from and to the
30 sea as required.

When a base unit is free floating, its lower valved
connections 97, 98 to ballast header manifold 94 will be
below the waterline of the base unit. Opening of these
connections and their attendant sea valves (not shown),
35 and suitable operation of control valves 96, will enable



1 the base unit to be ballasted in a free-flooding mode. By
closing valve 97 and the sea valve in connection 98 and
energizing the pump 100, water can be injected in a con-
trollable manner to assume a condition of negative buoyancy
5 in which the base unit comes to rest on sea floor 18 in a
fully submerged condition. In the case of initial mating
and assembly of the several components of structure 10,
the ballasting operations for a base unit will be discon-
tinued at that point since, during initial mating and
10 assembly, it is not necessary to fully ballast a grounded
base unit. Mating of the interconnected central units 14
with the grounded pair of interconnected bottom base units
12 can also be accomplished by use of the ballasting
procedure pertinent to grounding of the bottom base units
15 during the mating and assembly phase.

FIG. 22 shows the use of a valve chamber extension
trunk 102 to provide access by personnel into chamber 45
of a fully submerged base unit for purposes of ballasting
and deballasting the base unit. The lower end of trunk
20 102 is connectible to the double-entry hatch assembly 103,
previously described, which is installed to provide com-
munication between each base unit moonpool passage and the
adjacent valve and manifold chamber 45.

In the course of positioning fully assembled offshore
25 structure 10 at its intended site of use, it is necessary
to fully or substantially fill the ballast spaces of all
of the ballastable components of the structure to obtain
the desired gravity load of the structure upon the sea
floor. In these ballasting operations, valved connections
30 97, 98 to the ballast header manifolds in base units 12
will normally be below the waterline of the floating struc-
ture as it is positioned over the site of use. In some
instances, full ballasting of the base units can be com-
menced merely by opening valve connections 98. In other
35 instances, pertinent to some water depths, an upper tier



1 of the structure must be at least partially ballasted to
prevent the tier or tiers therebelow from sinking out from
under or away from such upper tier. The point, an important
one, is that careful attention must be given to ballasting
5 sequences to assure that firm contact between adjacent tiers
of structure 10 is maintained during the sinking operation.
As soon as the assembled structure engages the sea floor,
however, it becomes necessary to open the control valves
provided in suction ducts 47 to the moonpool passages of
10 base units 12. Thereafter, full ballasting of the compo-
nents, including filling of manifold and valve chambers
45 and 48, is accomplished through the use of submersible
pumps 100 connected to connections 97, 98 to the respective
chambers so that all of the ballast spaces in the ballas-
15 table components of structure 10 can be fully filled.

Deballasting of components involves a reversal of
pertinent ones of the procedures described above. The
ballast spaces in the base units can be drained down to
the level of the ocean by opening all of the manifold
20 valves and connections 97, 98 in or associated with the
respective manifold and valve chambers. Thereafter,
deballasting can be completed by the use of submersible
pumps 100 connected to the valve connections 97 and 98.

At at least one time during the useful life of each
25 component, it will be necessary to position that component
on the sea floor and then to refloat it from the sea floor.
To facilitate refloating of a component from an at-rest
position on a sea floor, each component is equipped with
jetting means for supplying pressurized sea water to a
30 multiplicity of points on its underside. The purpose of
this jetting system is to provide a means for overcoming
any suction force that will attempt to bind the component
to the sea floor upon which it rests. Some soils, such as
gravel or sand, may not require this mechanism. To refloat
35 a component from at-rest position on a sea floor by the



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1 use of the jetting system, it will normally be necessary
to fully deballast the component. The component can be
"peeled" from the sea floor by operating the jetting mech-
anisms in sequence from one edge of the component toward
5 the other. The jetting system includes a plurality of jet
nozzles which open through the bottom of the component at
selected locations over the area of the bottom. The jetting
nozzles are separately operable via suitable valves which,
preferably, are located either in the manifold and valve
10 chamber 45 for the component, or which can be located in
the pertinent ballast spaces.

Reinforced concrete barges having a honeycomb internal
definition generally as illustrated in FIG. 4 have previ-
ously been constructed using poured-in-place fabrication
15 techniques. Accordingly, the procedures and equipment
useful in constructing the base units of an offshore
structure according to this invention are generally known.
FIGS. 23 and 24 illustrate the general sequence of con-
struction of a reinforced concrete base unit module for
20 structure 10.

As shown in FIG. 23, a reinforced concrete bottom
slab 104 is first constructed in a suitable fabrication
facility. Then, using either cast-in-place techniques or
a fabrication procedure which involves precasting of indi-
25 vidual cylindrical cells 35, a central honeycomb cell and
intercell web arrangement 105 is erected on the bottom
slab in such manner that the cells and intercell webs are
integrally connected to the bottom slab, using known tech-
niques. As shown in FIG. 24 with reference to an intercell
30 web 36, the upper ends of all cells, whether they are the
circular cells 35, cruciform cells 37, or the elongate
cells defined between web walls 42, are all defined with
recesses 106 around their upper perimeters. Each recess
defines a receptacle for the placement across the upper

35



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1 end of each cell of a suitably configured precast, rein-
forced concrete closure or soffit, such as round soffits
107 for closing cells 35, and cruciform soffits 108 for
closing the cruciform cells 37; similar precast plank-like
5 rectangular soffits are provided for closing the cells
defined between adjacent ones of shear walls 42 and the
like. As prefabricated, the soffits all have reinforcing
bars 109 which extend laterally from them. Similarly,
before placement of the soffits in the corresponding
10 receptacles, the vertical walls of the cells have reinforc-
ing bars 110 which extend beyond the upper ends of the
walls as cast to define recesses 106; such wall upper
ends are represented by broken line 111 in FIG. 24. After
placement of the soffits in recesses 106, the projecting
15 ends of soffit reinforcing rods 109 are bent to assume a
substantially vertical position, as shown at 112 in FIG.
24, and the projecting ends of wall reinforcing rods 110
are similarly bent over, all to serve as part of the rein-
forcing bar network for a top slab 113 which is then poured
in place over the soffits and wall interim upper ends 111.
20 This completes the principal casting operation for each
base unit. The soffits function as forms for the pouring
of top slab 113, but remain in the cast concrete construc-
tion as functional elements of the construction.

25 The ability of offshore structure 10 to maintain its
desired position on sea floor 18 in the face of hori-
zontally applied loads depends upon the sliding resistance
presented by the subsea soil. This sliding resistance, in
turn, depends on shearing of the soil at a point below
that at which the structure engages the soil surface. To
30 enhance the sliding resistance of the bottom base units
along the sea floor, the bottom surfaces 54 of the base
unit modules of structure 10, and particularly the bottom
base units, can be configured as shown in FIGS. 25 and 26
to efficiently insure the coupling of the structure to the
35



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- 1 soil and obtain the full effective sliding resistance of the subsea soil.

As shown in FIGS. 25 and 26, a plurality of tapered longitudinal 117 and transverse 118 ribs are cast integral with the bottom slab 104 of base unit 12 to project a selected distance below slab bottom surface 54. The ribs are spaced regularly, and preferably the spacing, say, 12 inches, between the longitudinal ribs corresponds to the spacing between the transverse ribs. Also, as shown in FIG. 26, it is preferred that all of the ribs extend a common distance, say, 3 inches, below slab bottom surface 54. In this way, a waffle-type grid of projecting ribs is defined in the bottom surface of the base unit to enable the base unit, when landed upon a subsea soil and fully ballasted, to firmly grip and co-act with the adjacent subsea soil. A passage 119 is defined along surface 54 through each rib between the intersections of the rib with the ribs running at right angles to it across the surface. Passages 119 permit water to flow along the interface between the base unit and the subsea soil in lateral directions out from under the base unit as the mass of the base unit and offshore structure 10 acts to express water from the soil. As water is expressed from the soil engaged by the landed and fully ballasted offshore structure, the soil increases its consolidation, becomes stronger, and so takes on further enhanced resistance to sliding of the structure.

Those familiar with the fabrication of large concrete structures will appreciate that it is difficult to produce a truly flat poured surface of large expanse. The upper and lower surfaces of base units 12, 14 and 15 are very large in area, and therefore it will be difficult to cause these surfaces to be formed in a perfectly planar manner unless costly fabrication techniques are pursued. Therefore, it is likely, if not probable, that upon stacking the base



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1 units, opposing base unit surfaces 54 and 55 will not register perfectly with each other over the entire area of their interface 91.

5 To the extent that the surfaces defining horizontal interface 91 between stacked base units do not make perfect surface-to-surface contact, irregular contact between stacked components may produce unacceptable stress concentrations in the components. High stress concentrations in the concrete slabs, particularly near the middle of spans
10 between the vertical cells, webs and walls, can result in cracks in the concrete; similar problems can occur in steel base units. Therefore, it is desirable to provide a means for accommodating and eliminating the effects of surface irregularities in the interfaces between stacked
15 components. Such irregularities, undulations and deviations from perfect planarity in the opposed surfaces of stacked components is overcome and compensated by the use of a seating medium 120 in the interface between stacked components. The seating medium preferably is disposed upon
20 the upper surface 55 of each base unit which is to have another component placed upon it before the component is mated with the base unit in the performance of the procedures illustrated in FIGS. 10-19. The seating medium preferably is flowable or deformable under constant load,
25 while being inelastic, i.e., nonresilient, under rapidly applied loads.

FIG. 27, which is a cross-sectional elevation view of a portion of an interface 91 between stacked base units 12 and 14, illustrates the use of a layer of asphaltic concrete
30 or macadam 121 to define seating medium 120. FIG. 28, which is generally similar to FIG. 27, shows the use of a layer of sand 122 to define seating medium 120. Pea gravel or the like may be used in lieu of sand. Where the seating medium is provided by a layer of granular material, such
35 as sand or pea gravel, it may be useful to form the seating



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1 medium by use of a plurality of loosely woven, partially
filled bags containing the selected granular material.
Alternatively, it may be advantageous to use a cofferdam
which extends upwardly a short selected distance from the
5 lower component around the periphery of its upper surface
to keep deposited granular material in place on the surface
55 until it has been forcefully engaged by the upper
component and thereafter.

It is also within the scope of this invention that a
10 mechanical cooperation between suitably configured projec-
tions and recesses, defined by the component surfaces
forming an interface 91, may also be used to provide en-
hanced resistance to sliding between stacked components.
For example, inasmuch as the horizontal relative position-
15 ing between stacked base units is rather precisely defined
through the agency of shear pins 82 (see FIG. 20), the
upper surface 55 of each base unit could be cast or fabri-
cated to define projections which cooperate with a pattern
of depending ribs (see FIGS. 25 and 26) cast integral with
20 or fabricated on the bottom surface of the superadjacent
base unit.

As indicated in FIG. 1, an offshore structure which
has multiple tiers of base units is used in water depths
selected so that mean ambient water level at the site of
25 use is located substantially below the upper surfaces of
the uppermost tier of base units. Accordingly, ice pre-
sents the principal and predominant lateral load on the
structure in that portion of the height of the structure
which is defined by the base units. Deck units 17 will not
30 experience significant lateral loads. Accordingly, the
interface between deck units and base units will not expe-
rience high shear loads, and the use of interfitting pro-
jections between the deck units and the subadjacent base
units is not required for purposes of shear resistance.

35



1 FIGS. 1, 2 and 3 illustrate the presence of armor
belt 19 around the circumference of offshore structure 10
over that portion of the height of the structure which
commences a short distance above its mean waterline and
5 extends to a selected depth below the mean waterline.
Also, as noted above, armor belt 19 is defined by a plur-
ality of individual armor panels (see FIG. 2) which are
installed in essentially end-to-end relation around the
circumference of the pertinent tier of base units. It was
10 noted above that armor panels 23 and 24 are of uniform
height, say, 12 feet, but are provided in differing lengths,
say, 28 and 14 feet, respectively. The armor panels are
used to increase the inherent shell strength of the adjacent
base units and to provide a replaceable abrasion surface
15 for ice forces and motions. By providing local shell
thickening only at the ice belt area, the total dry weight
of the base units is reduced and minimum draft of the base
units is achievable. The armor panels are arranged, in
cooperation with related features defined by the base
20 units, to enable the armor panel belt to be installed at a
number of elevations on the assembled offshore structure.
The armor panels are readily replaceable in the event of
severe ice abrasion or other damage.

The presently preferred armor panels are 14 inches
25 thick as compared to the presently preferred 8 inch
thickness of base unit walls 38, 39, 41 and 42. When
present, the armor panels thus increase the local side
wall thickness to 22 inches, or about 40 percent of the
span of the adjacent base unit wall between shear walls
30 42. Each armor panel is attached by steel attachment
devices which are arranged to accommodate and transfer
to the adjacent base unit the shear and tension loads
imposed on the individual armor panel due to ice loads
applied laterally and vertically to the panel, due to
35 ice freezing to the panel, due to ice forming in the



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1 spaces between the panels and the base units, and due to the weight of the panels.

A large armor panel 23 is shown in elevation in FIG. 29. Each armor panel, whether it is an AP28 unit or an AP14 unit (see FIG. 2), preferably is of reinforced concrete construction and carries, at suitably spaced locations, six tension bolt socket assemblies 125, two shear pin socket assemblies 126, and one torque pin socket assembly 127. In mounting an armor panel to structure 10, all tension bolt assemblies 125, one of the two shear pin socket assemblies, and the torque pin assembly 127 are used. The tension bolt assemblies (see FIG. 34) are provided for accommodating loads tending to move the mounted armor panel away from the adjacent base unit. The shear pin assemblies (see FIGS. 30 and 31) are used to carry all shear loads applied to the panel in the basic plane of the panel. The torque pin assembly (see FIGS. 32 and 33) is used to secure the panel from rotating about the shear pin and prevent shear in the tension bolts.

20 In each armor panel, tension bolt socket assemblies 125 are disposed in two vertical rows of three assemblies each. In each row, the socket assemblies are spaced on 4 foot centers. The spacing between the two rows of assemblies in each armor panel is an integral multiple of the spacing between adjacent shear walls 42 in each of the base units. The two shear pin socket assemblies 126 carried by each armor panel are also disposed vertically relative to each other and are spaced on 4 foot centers midway between the two rows of tension bolt socket assemblies. When the armor panel is mounted to a base unit, the shear pin socket assemblies lie adjacent the center of a base unit cell formed between two adjacent shear walls 42. The torque pin socket assembly 127 in each armor panel is located as far as practicable from the shear pin socket assemblies, preferably in an upper



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1 corner of the panel at such location in the panel that,
when the panel is mounted to a base unit, socket assembly
127 is aligned substantially midway between two adjacent
shear walls 42 in the base unit.

5 FIG. 30 is an elevation view, with parts broken away,
of a shear pin socket assembly for an armor panel. In
FIG. 30, a shear pin cover plate 128 (see FIG. 31) has
been removed, and the concrete in the adjacent portions of
the panel has been removed to illustrate that a panel
10 shear pin socket member 129, preferably a massive casting,
is securely connected to the steel reinforcing rods 130
within the panel, as by welds 131. Socket 129 has a thick-
ness of 14 inches, i.e., a thickness equal to the thickness
of the reinforced concrete which defines the principal
15 portions of the armor panel. A circular bore 132 is formed
centrally through socket 129 along an axis which is perpen-
dicular to its front and rear surfaces. A preferably
hollow and thick walled cylindrical shear pin 133 cooperates
in bore 132 and with a bore 133 defined in a receiver
20 member 134 which is a feature of the base unit. Receiver
135 is securely connected to the base unit reinforcing
rods 136 by welds 137, as shown in FIG. 31. The inner end
of receiver bore 134 is closed by a closure plate 138. An
annular rubber or neoprene cushion pad and gasket 139 is
25 disposed between the outer surface of the base unit and
the reverse side of the armor panel around the shear pin
in the mounting of the panel to the base unit.

Two shear pin socket members 129 are located in each
armor panel and are spaced vertically in the panel on 4
30 foot centers. The upper one of these members 130 is
aligned with the upper ones of tension bolt socket assem-
blies 125 in the panel. In each base unit, however, shear
pin socket members 135 are located in a vertical array on
8 foot centers. This difference between the vertical
35 spacing of members 129 in each armor panel and the spacing



1 between cooperating members 135 in the base units means
that an armor panel can be secured to a base unit at any
one of a number of discrete positions spaced 4 feet apart
vertically along the base unit.

5 To mount an armor panel to structure 10, the panel is
lowered, by use of lifting fixtures 140 carried on the
upper edge of each panel, from the upper deck 31 of the
structure to the desired vertical position adjacent the
exterior of the structure where one of bores 132 in the
10 panel is aligned with a bore 134 in the base unit hull.
The shear pin 133 can be present in bore 132 to project
from the rear of the panel. Thus, as the panel is lowered
into position, the tapered inner end of the shear pin can
slip readily and quickly into bore 134. The single shear
15 pin which cooperates between each armor panel and the
adjacent base unit carries all of the weight of the panel
as well as loads which may be applied to the panel both
vertically and horizontally by ice incident upon the panel.

Once the weight of an armor panel has been transferred
20 to an adjacent base unit via a shear pin 133, tension bolt
socket assemblies 125 and their cooperating receiver assem-
blies 141 in the base unit are used, in combination with
torque pin socket assembly 127, to secure the armor panel
to the base unit. As shown in FIG. 34, the panel tension
25 bolt socket assemblies 125 are metal constructions which
may be of the built-up weldment type as shown in FIG. 34,
or formed by suitable castings. Each assembly 125 includes
a panel socket member 142 which is securely affixed to the
reinforcing rods 130 of the panel prior to casting the
30 concrete. The panel socket member extends between the
forward and rear sides of the panel. The socket member
defines a recess 143 having a bottom surface 144. Recess
143 is sized sufficiently to receive within the recess
the entirety of the head of a tension bolt 145 when the
35 shank of the bolt is passed through a bore 146 formed in



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1 surface 144. Bore 146 communicates to the rear surface
of the panel. Each tension bolt 145 has a length which is
substantially greater than the thickness of the armor
5 panel. The threaded end of each tension bolt cooperates
in a threaded socket 147 defined by the cooperating hull
tension bolt receiver 141 which is carried in the adjacent
base unit 12, for example, to be flush with the outer
surface of base unit wall 38, for example. Receivers 141
10 are each carried at a predetermined location in the base
unit determined with reference to the location in the base
unit of the pattern and location of shear pin socket members
135 and with reference to the pattern and positioning of
panel tension bolt socket assemblies 125 in the several
armor panels. The rear end of receiver 141 is securely
15 affixed, as by welding or threading, to one end of an
elongate embedment rod 148. The several receiver assemblies
are carried in the walls of the base units in line with
selected ones of shear walls 42. Accordingly, embedment
rod 148 extends a substantial distance from its cooperating
20 receiver 141 into the concrete which defines the pertinent
base unit shear wall.

Inasmuch as it is known in advance of placement of
offshore structure 10 at the intended site of use approxi-
mately where the mean waterline of the installed structure
25 will lie vertically on the structure, it is possible to
ascertain before final positioning of the offshore struc-
ture which of the several receiver assemblies 141 will be
used for the mounting of armor panel belt 19 to the perti-
nent base units. Once it is known which receivers 141
30 will be used in mounting the armor panel belt to structure
10, an annular resilient cushion pad 149 formed of, say,
neoprene or rubber, is bonded to the outer surface of the
base unit substantially coaxially of the designated receivers.
Preferably cushion pads 149, which have the same thickness
35 as cushion pads 139 used with the shear pin assemblies,



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1 are applied to the exterior surfaces of the pertinent base
units at that point in the sequence of operations illus-
trated in FIGS. 10-19 when the pertinent base units have a
draft adequate to provide ready access to the designated
5 receivers.

The details of a torque pin socket assembly 127 for
an armor panel 23, 24 are shown in FIGS. 32 and 33; FIG.
33 also shows details of one of the several hull torque pin
receivers 152 which are carried by each base unit in asso-
10 ciation with each group of possible positions of an armor
panel on its outer walls. As shown in FIGS. 32 and 33,
each panel torque pin socket 127 is comprised of a heavy
metallic socket member 153 which can be either a weldment
or a casting, which is securely affixed to the reinforcing
15 rods 130 of the panel, and which extends from front to
back through the armor panel at a predetermined location
in the panel. Socket member 153 defines a passage 154
which is open entirely through the panel. The passage is
non-round, preferably rectangular, in cross-section and is
20 wider than it is high (see FIG. 32). An elongate torque
pin 155 which preferably is a built-up construction of
non-round, preferably rectangular, cross-section, coop-
erates in passage 154 and in a tapered recess 156 formed
in hull receiver member 152. Recess 156 is also rectangu-
25 lar in configuration, similar to the configuration of
recess 154. Recess 156 is tapered (as shown in FIG. 33)
in that the rear portions of its top and bottom sur-
faces converge linearly toward each other. The rear end
of recess 156 is closed by a suitable closure plate 158.
Receiver 152 is a relatively massive member which is securely
30 affixed to the reinforcing rods 136 disposed in base unit
wall 38, for example, so that any loads applied to receiver
152 are safely borne and transferred to the overall structure
of base unit 12.

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1 Shear pin 155 has vertical side walls and top and
bottom walls which are parallel to each other centrally
of the length of the shear pin. Adjacent the rear end of
the shear pin, i.e., the end of the shear pin which is
5 engageable in recess 156, the top and bottom surfaces of
the pin converge linearly at the same slope as defined by
the taper of the top and bottom walls of recess 156 toward
its rear end. Also, the top and bottom surfaces of the
pin slope toward each other, as at 159, at the forward
10 portion of the pin.

Preferably the torque pin for each armor panel is
fully engaged in its seating passage 154 and recess 156
after tension bolts 145 have been engaged with their
receivers 141 but before the tension bolts are fully
15 tightened, thereby enabling the torque pin to be installed
while limited angular movement of the armor panel about
its shear pin 133 is still possible. Installation of the
torque pin 155 involves insertion of the torque pin into
passage 154 and into seated engagement with recess 156
20 with which socket assembly 127 is substantially aligned
following engagement of the panel shear pin in its receiver.
Such insertion of the torque pin includes passage of the
pin through a resilient cushion pad 160 which is similar
to cushion pads 139 and 149 and which preferably is pre-
25 fitted to the pertinent torque pin receiver at the same
time as cushion pads 139 and 149 are prefitted to the
corresponding base unit. Following seating of the inner
end of the torque pin in recess 156, a pair of wedges 162
are driven into engagement between the tapered portions
30 159 of the pin top walls and the adjacent walls of passage
154. The wedges are tack-welded in place to cause the
torque pin to be securely and snugly engaged within socket
assembly 127. The portions of passage 154 and recess 156
which are not occupied by torque pin 155 are packed with a
35 suitable grease or the like. The open forward end of



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1 passage 154 is then secured by a suitable closure 163 so
that the forward surface of panel 23 is smooth across the
location of the shear pin socket assembly. Thereafter,
5 the several tension bolts 145 for the armor panel are
tightened to securely clamp the armor panel to the adjacent
base unit in the precise position defined by the combined
effect of shear pin 133 and torque pin 155. The panel
then cannot move linearly parallel to the adjacent base
10 unit wall surface by reason of the effect of the shear
pin, and the panel cannot move angularly relative to the
adjacent base unit because of the effect of the torque
pin.

It was noted above that each armor panel is mountable
to the adjacent base unit at a number of positions which
15 are spaced vertically 4 feet apart along the base unit.
In order that such positional variation can be achieved
through the use of armor panels which carry only one torque
pin socket assembly 127, it will be apparent that each
base unit must include a suitable number of torque pin
20 receivers 152 at each station on the perimeter of the base
unit where an armor panel can be mounted. The torque pin
receivers at each station are spaced vertically on 4 foot
centers in the pertinent base units.

FIG. 35 shows that there may be some applications and
25 uses of an offshore structure according to this invention
in which it is desirable or required that the structure be
used in combination with some other arrangement or device
installed at sea floor 18 at the intended site of use of
the offshore structure before the final placement of the
30 structure at the site. This is particularly true in the
instance of oil and gas well drilling operations, or in
the production of oil and gas from completed production
wells. In the illustrative instance of exploratory well
drilling operations, FIG. 35 shows offshore structure 10
35 outfitted as a drilling facility in use over a subsea



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1 cellar structure 170 which is adequately sized to define
one or more upwardly open chambers 171. The chambers are
provided for receiving blowout preventers 172 and other
5 associated wellhead drilling equipment below mudline, i.e.,
the upper surface of subsea soil layer 18. Offshore struc-
ture 10 is positioned at the site of use so that its vertical
moonpool passages align with the cellar structure. In the
event that structure 10 should ever be moved laterally
10 along the sea floor in response to displacing forces, the
production equipment located in cellar chambers 171 can be
undisturbed and undamaged.

FIG. 36 illustrates the versatility afforded to vari-
ous Arctic operations by use of offshore structures accord-
ing to this invention. FIG. 36 illustrates that the lower
15 tier of a production drilling offshore structure 10' accord-
ing to the foregoing description, and defined of base units
of suitable relative heights, can be left in place on sea
floor 18 at the completion of production as the central
tier of structure 10' and all components and equipment
20 carried by the central tier are moved away to be replaced
by a central and upper tier assembly of a second offshore
structure 175 outfitted with an operations facility 176
adapted for production and processing of oil and gas
from wells completed by use of structure 10'. Offshore
25 structure 175 is a subcombination of the modular compo-
nents of an offshore structure according to this invention
(see FIG. 2) which can be moved into alignment with and
registry with lower tier 11 within hours following the
removal of the upper portions of structure 10' from the
30 location.

Thus, it is seen that this invention makes possible the
rapid, efficient and effective installation of a production
facility at a desired offshore site in the Arctic promptly
upon completion of the wells to be produced. Removal of
35 the central and upper portions of structure 10' from lower



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1 tier 11 (which remains in place in a fully ballasted condi-
tion on sea floor 18) can be accomplished by withdrawing
vertical shear pins 82 from their receiving sockets 83 in
the base units comprising lower tier 11, and by at least
5 partially deballasting the ballast spaces in the base
units and deck barges defining the upper portions of
structure 10'. Offshore structure 175 is quickly, effi-
ciently and safely matable with the base units of tier 11
by use of the procedures described above and illustrated
10 in FIGS. 17, 18 and 19, for example. Production drilling
platform 10', following removal from its site of use as
illustrated in FIG. 36, can be mated with a new or differ-
ent offshore structure lower tier (composed of suitably
sized bricks, BB44, BB32, BB17 or the like) for installa-
15 tion at a new site of use by application of the procedures
illustrated in FIGS. 15-19, for example.

It is within the scope of this invention that an
offshore structure according to this invention can be
defined by a single honeycomb reinforced concrete brick-
20 like base unit of suitable dimensions, if desired. FIG.
37 illustrates a very large base unit 180 suitable for
defining a single brick tier of an offshore structure.
Base unit 180 is, in effect, the combination of the two
base units 12, for example, provided as a single integral
25 unit rather than a mated pair of smaller units. The factors
which determine the practical efficacy of the use of base
unit 180 include the availability of construction facili-
ties of suitable size and capacity, the location of such
construction facilities relative to the intended site of
30 use of base unit 180, and factors pertinent to the movement
of such a large base unit from the construction site to
its site of use, among other things.

The honeycomb compartmentalization and reinforced con-
crete construction of the preferred base units of an offshore
35 structure as described above provide definite and attractive



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1 advantages over other structural framing systems and construction approaches. The concrete base units are economical and can be constructed with ease. They provide superior structural strength and rigidity. The honeycomb compartmentalization of the base units affords easy variation in
5 compartmentalization within the base units. The high compartmentalization of the base units provides excellent control over the submergence procedures which have been described above. Reinforced concrete structures are very resistant
10 to damage and are quite advantageous in terms of pollution prevention. Concrete is corrosion resistant, spark resistant and fireproof; the reinforced concrete base units provide excellent safety considerations, and they have enhanced reliability and maintainability characteristics
15 and are readily field repairable. Moreover, an offshore structure according to this invention has additional advantages. The use of modularization makes it possible to construct the individual components of the structure concurrently in different construction facilities which
20 may be located in diverse locations worldwide; individual components of the structure can be built in those facilities where greatest expertise is available, or the greatest economies can be realized. The structure has a low life-cycle cost applicable to a long operational period. The
25 modular components can be fabricated in industrialized areas at existing sites and towed to the Arctic site of use. No dredging, or only minimal dredging is required at the site of use for installation or relocation. The replaceable armor panels which have been described are
30 added at the ice line experienced by a particular structure to protect the base structure without suffering a weight penalty to the entire side wall areas of the structure. An offshore structure according to this invention uses sea water ballast and so avoids the use of special dredging
35 and transfer of other ballast materials or the use of



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1 special fluids. The structure can be refloated, moved and
re-used over and over. Sound transmission through concrete
is low and so marine life is virtually unaffected by the
use of an offshore structure according to this invention.
5 In extreme circumstances during Arctic use of the offshore
structure, conventional ice defense procedures can be
practiced to keep the structure from experiencing environ-
mental forces in excess of reasonable design limits.

It is a feature of this invention that the various
10 modular components, provided by the kit of components
illustrated schematically in FIG. 2, can be selected and
assembled to provide a wide range of specific offshore
structure configurations suited to a wide range of usage
conditions and locations. For example, an offshore struc-
15 ture comprised of BB32 and DSB or DSBR components is
usable in water depths in the range of from 18-30 feet.
An offshore structure composed of BB44 and DSB or DSBR
modules is usable in water depths in the range of from
24-42 feet. An offshore structure, such as structure 10
20 shown in the accompanying drawings, composed of modules
BB44, BB32 and DSB, DSBR, IDU or equivalent modules can be
used in water depths ranging from 37-60 feet. Other off-
shore structures usable in different water depths can be
assembled and defined by use of other combinations of the
25 components shown in FIG. 2 or other modules consistent
with the foregoing descriptions.

The modular components for an offshore structure
according to this invention are provided pursuant to an
integrated approach which has carefully considered and
30 addressed pertinent environmental, design and logistics
criteria. For example, the presently preferred offshore
structure 10 which has been described above is suited for
use in Arctic applications where the following environmental
criteria are applicable.

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TABLE IENVIRONMENTAL CRITERIA

5	°	Air Temperature	-	60°F to +70°F
	°	Wind Speed	-	70 Knots (Survival)
	°	Significant		
		Wave Height	-	14 Feet (10 Year Storm)
10	°	Water Depth	-	18 to 52 Feet
	°	Current	-	3 to 4 Knots (10 Year Storm)
	°	Tide	-	6 to 12 Inches
	°	Ice Thickness	-	0 to 6.5 Feet
15	°	Movement Velocity		
		Outside Barrier		
		Islands	-	50 Feet/Hour
		Inside Barrier		
20		Islands	-	8.4 Feet/Hour
	°	Ice Load		
		- Global Crushing		
		Inside Barrier		
25		Islands	-	240 Kips/Foot
		Outside Barrier		
		Islands	-	460 Kips/Foot
		- Local Impact	-	600 Psi (over a 5 x 28 Foot Area)
30		- Breakout Shear	-	50 Psi
		- Breakout Tension	-	50 Psi
	°	Ice Defense	-	None
	°	Soil		
35		Characteristics	-	Over-Consolidated Clayey Silts
	°	Allowable Soil		
		Bearing	-	6.0 Kips/Ft ²



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- 1 Such an offshore structure is consistent with and respects the following design criteria.

TABLE IIDESIGN CRITERIA

5			
10	•	External Hydrostatic Head	- 64 Feet-Bottom BB (At Installation)
	•	Minimum Safety Factors:	
		- Sliding, Overall	- 1.5
		- Ice Load	- 1.3
15		- Hydrostatic Load	- 1.5
		- Soil Bearing	- 2.5
	•	Classification	- ABS/USGS

20 Also, the following logistics criteria are pertinent to offshore structure 10.

TABLE IIILOGISTICS CRITERIA (4 MONTH SUPPLY)

25	•	Drill Mud & Chemicals (Dry)	- 45,000 Sacks
	•	Drill Mud Active (Liquid)	- 1,000 Barrels
30	•	Drill Mud Reserve (Liquid)	- 4,000 Barrels
	•	Cement (Bulk)	- 10,000 Cubic Feet
	•	Drill Water Usage	- 375 Barrels per Day
	•	Drill Water Storage with Desalination	- 1,000 Barrels
35			



1 TABLE III (Cont'd)

	•	Drill Water Storage		
		without Desalination	-	45,000 Barrels
	•	Fuel Usage	-	5,000 Gallons per Day
5	•	Fuel Oil Storage	-	16,000 Barrels
	•	Cuttings Storage	-	3,000 Barrels
	•	Casing Storage	-	Sufficient for
				One Production Well

10 The features of modularity and stackability of the components of an offshore structure according to this invention are not limited to the use of structure components defined only of reinforced concrete. The use of reinforced concrete base units in the practice of this invention is presently
15 preferred and is regarded as the best mode of practicing the invention, and the preceding description has addressed the use of reinforced concrete base units for these reasons. However, the benefits of modularity and stackability of components of an offshore structure can also be realized
20 through the use of base units constructed of steel, preferably steel base units having geometries, configurations, dimensions, and external features the same as or compatible with the same characteristics of the concrete base units described above. Steel and concrete base units can be
25 intermixed and interengaged as desired.

Base units fabricated entirely of steel can be lighter than equivalent base units fabricated of reinforced concrete, thus providing base units having reduced unballasted draft. In some sites of use, minimum draft properties may be
30 important.

In the context of base units fabricated of steel, it is presently preferred to define the base units as modifications of the tank spaces of tanker ships or other very large cargo carriers. There is presently a large worldwide
35 supply of tankers which have been or are being retired from



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1 service, and which will be broken up for scrap unless other
uses for them, or for portions of them, can be found. The
use of a tanker midbody, with modifications, to define a
base unit for an offshore structure of this invention can
5 have the benefit of short construction time to better meet
an urgent need for the benefits of this invention.

Thus, the scope of this invention can encompass an
offshore structure composed of plural tiers of modular
structural components in which all base unit components are
10 fabricated of reinforced concrete, or in which all base
unit components are fabricated of steel, or in which the
base units are composed of a mix of some reinforced concrete
units and some steel units.

The foregoing descriptions, and the accompanying draw-
15 ings with reference to which such descriptions have been
made, set forth presently preferred and other exemplary
embodiments of this invention. Neither the foregoing
description nor the accompanying drawings are intended to
constitute, nor should they be interpreted to be an exhaus-
20 tive catalog of all forms of the structures and procedures
which may be adopted as embodiments and manifestations of
this invention. Rather, the preceding description and the
accompanying drawings have been presented illustratively,
by way of example, and in furtherance of an exposition of
25 the presently known best mode for practicing the structural
and procedural aspects of this invention. Variations in
the structures and procedures described may be practiced
without departing from the true scope and content of this
invention. Accordingly, the preceding descriptions and
30 accompanying illustrations shall not be interpreted to
restrict the following claims to less than their fair
scope.



1 WHAT IS CLAIMED IS:

1. An arctic offshore structure of the gravity type movable buoyantly to and from a site of use on a sea floor, under waters in a selected range of depths, the structure when installed at the site extending from a lower end substantially at the sea floor through and above the water surface to an upper operations end of the structure which is adapted to carry a selected operations facility, the structure in a portion thereof between its lower end and a location in the structure a selected distance above the water surface having substantially vertical and substantially flat outer walls, the structure in said portion being comprised of at least one base unit, each base unit being floatable, the structure being reversibly ballastable adequately to impart to the structure sufficient negative buoyancy, in combination with the nature of the sea floor, to maintain a desired position at the site under environmental forces applied horizontally to the structure.

20 2. Apparatus according to claim 1 wherein at least one of the base units is fabricated of reinforced concrete arranged within the unit to define a plurality of vertical cells and intercell webs.

25 3. Apparatus according to claim 2 wherein each reinforced concrete base unit has top and bottom slabs and the cells and webs extend between the slabs, a portion of the interior of each such base unit being defined by substantially circular vertical cells located on centers spaced farther than the cell diameters and interconnected by the webs, other portions of the interior of each such base unit adjacent at least some of the base unit outer walls being defined by vertical inner walls disposed substantially normal to and intersecting the immediately adjacent outer walls.

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- 1 4. Apparatus according to claim 3 wherein the inner
walls extend from the outer walls to vertical bulkhead walls
which extend between the top and bottom slabs.
- 5 5. Apparatus according to claim 1 wherein the structure
defines a passage vertically therethrough.
- 10 6. Apparatus according to claim 1 including a cavity
in each base unit, a duct communicating from the cavity
through an outer wall of the base unit, and ballast means
operable for ballasting and deballasting the base unit from
and to the cavity.
- 15 7. Apparatus according to claim 6 wherein the interior
of each base unit is subdivided to define a plurality of
ballast spaces, and the ballast means includes a chamber in
the base unit adjacent the cavity, duct means communicating
each ballast space to the cavity via the chamber, and valves
in the duct means operable in the chamber for establishing
20 and regulating communication from each ballast space to the
cavity.
- 25 8. Apparatus according to claim 7 including vent means
communicable from the upper extent of each ballast space to
the cavity.
- 30 9. Apparatus according to claim 7 wherein each cavity
includes a ballast manifold having a valved connection to
each ballast space in the base unit, and plural valved con-
nections from the manifold to the exterior of the cavity.
- 35 10. Apparatus according to claim 9 wherein the cavity
in at least one base unit opens through the top and bottom
surfaces of the base unit.



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1 11. Apparatus according to claim 7 including means for heating the ballast spaces in each base unit.

5 12. Apparatus according to claim 1 wherein the interior of each base unit is subdivided into a plurality of water ballast spaces, and means for heating water in the ballast spaces.

10 13. Apparatus according to claim 1 wherein the structure is composed of plural tiers of modular components of the structure including at least one base unit tier in a lower portion of the structure each defined by at least one base unit and an upper tier defined by at least one ballastable barge unit.

15 14. Apparatus according to claim 13 wherein the base unit tiers have substantially equal dimensions of length and width.

20 15. Apparatus according to claim 14 wherein each base unit tier is composed of a pair of base units of equal height and length.

25 16. Apparatus according to claim 15 wherein the upper tier is composed of a pair of barge units.

17. Apparatus according to claim 16 wherein each barge unit is defined for carrying a base unit.

30 18. Apparatus according to claim 17 wherein each barge unit is operable as a submersible barge.

35



1 19. Apparatus according to claim 15 wherein each base
unit in each tier has a side wall arranged to face the side
wall of the other base unit of the tier in the structure, the
side walls of the two base units having registrable features
5 operative upon registration for securing the base units from
selected movements relative to each other.

20. Apparatus according to claim 19 including connection
means releasably connected between the base units in each
10 base unit tier operative for securing the connected base
units from other movements relative to each other.

21. Apparatus according to claim 13 including means
cooperating between tiers of the structure for securing
15 the tiers from movement laterally relative to each other.

22. Apparatus according to claim 21 wherein the means
cooperating between tiers includes vertical pin means.

20 23. Apparatus according to claim 21 wherein the means
cooperating between tiers includes a locally deformable
layer of inelastic material disposed between base unit tiers.

24. Apparatus according to claim 13 wherein each tier
25 of the structure is composed of a pair of similar modular
components each having a length dimension at least about
twice a width dimension thereof, the components in each tier
being disposed with their length dimensions transverse to
the length dimension of the components in each adjacent
30 tier.

25. Apparatus according to claim 1 including an armor
belt of selected height carried by the structure about its
circumference in said portion of the structure.

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1 26. Apparatus according to claim 25 wherein the armor belt is comprised of a plurality of discrete armor panels each of the selected height.

5 27. Apparatus according to claim 26 wherein the armor panels are fabricated of reinforced concrete.

10 28. Apparatus according to claim 26 including panel connection means releasably connectible between each panel and the adjacent base unit for securely connecting the panel to the base unit.

15 29. Apparatus according to claim 28 wherein the panel connection means includes plural connection features carried by each panel in a selected pattern, and a greater number of cooperating connection features carried by the adjacent base unit in respect to each panel in an arrangement corresponding to the selected pattern and to vertical extensions thereof, whereby each panel is connectible to the adjacent base unit at each of plural vertically-spaced discrete positions on the base unit.

20 30. Apparatus according to claim 28 wherein, for each panel, the connection means include first connection means for carrying shear loads between the panel and the adjacent base unit, second connection means operative for carrying torque loads between the panel and the base unit, and third connection means for carrying loads urging the panel away from the base unit.

30 31. Apparatus according to claim 30 wherein each connection means includes a resilient member disposed between the panel and the base unit.

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1 32. Apparatus according to claim 26 wherein each armor panel has a thickness greater than the thickness of the adjacent outer wall of the adjacent base unit.

5 33. Apparatus according to claim 1 wherein the base unit defining the lower end of the structure has a bottom surface from which extend for a selected distance a plurality of ribs, the ribs extending in orthogonal directions across the bottom surface and intersecting each other.

10 34. Apparatus according to claim 33 including a passage through each rib parallel to and adjacent the base unit bottom surface between adjacent intersections of the rib with other ribs.

15 35. Apparatus according to claim 1 including means carried by each base unit defining the lower end of the structure operable for forcing water under pressure through a bottom surface of the base unit at selected locations on the bottom surface.

25

30

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1 36. A mobile gravity structure for offshore marine use
in water having a depth within a selected range of depths,
the structure comprising a plurality of tiers of prefabricated
5 modular structural units cooperatively structurally inter-
related and equipped to cause the structure to have a desired
geometry and desired suitability for an intended use in a
selected environment, the units including at least one base
unit of selected height having top and bottom surfaces and
10 substantially vertical outer walls, means cooperable between
units for securing the units from relative movement in
response to environmental forces, each unit having a buoyant
state, ballast means operable for controllably ballasting
each unit between its buoyant state and a state of reduced
15 buoyancy which for the base units is a nonbuoyant state, the
several units being assemblable into the structure by
selective ballasting, deballasting and mating of the units
in a predetermined sequence, the several units when assembled
being floatable as an entity into and out of partially
20 submerged forceful engagement with a sea floor in waters
within the selected range of depths.

37. Apparatus according to claim 36 wherein each tier
is composed of at least two modular structural units, the
units in each tier having a common height, and means for
25 connecting together the units in each tier.

38. Apparatus according to claim 37 wherein each
modular structural unit has a length substantially greater
than a width thereof, the units in each tier being matable
30 with units in the next lower tier of the structure with
the lengths thereof oriented transversely of the lengths
of the units in the next lower tier.

35



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1 39. Apparatus according to claim 36 wherein the
structure includes an upper tier and at least one additional
tier therebelow, the structure in the portion thereof defined
by the additional tiers having substantially flat vertical
5 walls.

 40. Apparatus according to claim 39 wherein the
structure in said portion has essentially equal dimensions
of width and length.

10 41. Apparatus according to claim 39 wherein the
structure in said portion has a geometry substantially that
of a square pillar having chamfered corners.

15 42. Apparatus according to claim 36 wherein the
structure, when disposed in partially submerged engagement
with a sea floor, has a waterline at a tier defined by at
least one of the base units, and armor means attachable to
the waterline tier for defining an armor belt around the
20 structure at the waterline.

 43. Apparatus according to claim 42 wherein the armor
means comprises a plurality of reinforced concrete armor
panels individually attachable to the structure waterline
25 tier, the armor panels each having a thickness greater than
the thickness of the base unit outer walls.

 44. Apparatus according to claim 36 further compris-
ing a unitary base assembly engageable directly with a sea
30 floor in a fully submerged state, the base assembly having
an upper end adapted to receive and support the mobile
gravity structure via the lower tier thereof.

35



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1 45. Apparatus according to claim 44 wherein the mobile gravity structure at the lower tier thereof has selected dimensions of length and width, and the base assembly has substantially greater dimensions of length and width.

5

 46. Apparatus according to claim 45 wherein the base assembly has side walls which slope outwardly and downwardly from the upper end of the assembly.

10

 47. Apparatus according to claim 36 wherein the modular structural units of the structure are cooperatively configured and arranged to define, upon assembly thereof into the structure, an open passage vertically through the structure at a selected location in the structure inwardly
15 of the base unit outer walls.



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1 48. A set of modular structural units of coordinated
and cooperatively related configuration and arrangement
assemblable in selected numbers and arrangements to define
one of a series of possible mobile gravity structures for
5 marine use in a selected range of water depths within a
wider range of water depths pertinent to the series, the
set comprising at least one of each of the following
modular structural units:

- 10 a. a deck unit of selected height, length and
width fabricated of steel and arranged to define
an upper deck of a mobile gravity structure,
b. a first base unit of selected height, length
and width and having vertical essentially flat
outer walls extending between top and bottom
15 surfaces, and
c. a second base unit of selected height different
from the height of the first base unit and having
length and width essentially equal to that of the
first base unit and vertical essentially flat
20 outer walls extending between top and bottom
surfaces,

each modular structural unit being floatable and including
ballast means operable for controllably ballasting and
deballasting the unit between positively and substantial
25 negatively buoyant states.



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1 49. Apparatus according to claim 48 wherein the set
comprises two substantially similar deck units, a third base
unit similar to the first base unit, and a fourth base unit
similar to the second base unit, and wherein the base units
5 have lengths greater than their widths and each deck unit
has a bottom surface having length and width dimensions
essentially equal respectively to the base unit lengths and
widths, and connection means releasably cooperable between
the first and third base units, between the second and fourth
10 base units, and between the deck units' for connecting such
units in side-by-side relation.

50. Apparatus according to claim 49 wherein each deck
unit is operable as a submersible barge and, in the positively
15 buoyant state, is capable of supporting the larger of the
first and second base units thereon.

51. Apparatus according to claim 49 wherein the modular
structural units are defined to be stackable in tiers com-
20 posed of the deck units as an upper tier, and at least two
base units of equal height as an additional tier with the
lengths of the units in each tier disposed transversely of
the lengths of the units in the tier next therebelow, and
means cooperable between units in adjacent tiers for securing
25 the units from lateral relative movement.

52. Apparatus according to claim 51 wherein the units
of the set are cooperatively configured to define, upon
stacking thereof in predetermined positions and relations,
30 at least one passage vertically through the units.



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1 53. Apparatus according to claim 48 wherein the modular
structural units are defined to be stackable and are coop-
eratively configured to define, upon stacking thereof in
predetermined positions and relations, at least one passage
5 vertically through the units.

 54. Apparatus according to claim 48 wherein the set
further comprises a plurality of armor panels of selected
thickness greater than the thickness of the outer walls of
10 either base unit and of selected height, and mounting means
defined by and cooperable between the base units and the
panels for mounting the panels to the outer walls of a base
unit as a belt substantially around the base unit.

15 55. Apparatus according to claim 54 wherein the mount-
ing means are defined for mounting of the panels to a base
unit at any one of several locations vertically on the base
unit outer walls.

20 56. Apparatus according to claim 48 wherein the set
further comprises a submergible base assembly fabricated of
steel and configured to directly engage a sea floor of
predetermined nature and to provide a substantially level
top surface with which a base unit is engageable for support
25 by the base assembly.

 57. Apparatus according to claim 54 wherein each armor
panel is fabricated principally of reinforced concrete.

30 58. Apparatus according to claim 48 in which at least
one of the base units is fabricated of reinforced concrete
arranged within the unit to define a plurality of vertical
cells and intercell webs.

35



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1 59. An armor panel for use with an offshore structure
supported on a sea floor and extending through the surface
of water on which ice may float, the structure having a
flat vertical outer wall to which the panel is mountable,
5 the panel comprising a substantially uniformly thick member
of selected height and width and having front and rear
surfaces, and mounting means carried by the panel operable
for mounting the panel to the structure outer wall in coop-
eration with cooperating means carried by the structure,
10 the panel mounting means including a first socket in the
panel at a selected location in the height of the panel
substantially centrally of the width thereof and open through
the panel rear surface for receipt of a round panel support
member, a second socket in the panel in substantial spaced
15 relation to the first socket and open through the panel rear
surface for receipt of an elongate torque resisting member,
and a plurality of passages through the panel from the front
to the rear surfaces thereof for receipt of tension members
operable for holding the panel against the structure outer
20 wall.

60. Apparatus according to claim 59 wherein the second
socket is configured for receipt of a non-round torque
resisting member.

25

61. Apparatus according to claim 59 including a round
support pin receivable in the first socket and in a coop-
erating feature defined in the structure outer wall, a torque
resisting member receivable in the second socket and in a
30 cooperating feature defined in the structure outer wall, and
a plurality of threaded tension members insertable through
the passages and into threaded engagement with cooperating
features defined in the structure outer wall.

35



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1 62. Apparatus according to claim 59 including a third
socket essentially identical to the first socket located in
the panel vertically of the first socket and spaced a
predetermined distance from the first socket.

5

63. Apparatus according to claim 59 wherein the first
and second sockets are defined by passages through the
panel, and means for closing the socket passages at the
panel front wall.

10

64. Apparatus according to claim 59 wherein the panel
member is fabricated principally of reinforced concrete.

15



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- 1 65. A method for assembling and installing at a
selected offshore site a surface-piercing, bottom-supported
multi-tier offshore structure comprising the steps of
- 5 a. providing each of the tiers of the structure as
floatable constructions capable of being ballasted
between positively and negatively buoyant states,
- 10 b. at an assembly location in waters deeper than
the sum of the light draft of the upper tier and
the height of the second tier, and shallower than
the sum of said height and a deep draft floating
state of the first tier construction,
- 15 1) ballasting the second tier construction to its
negatively buoyant state to place it on the sea
floor,
- 20 2) positioning the first tier in a floating state
over the second tier construction in a selected
orientation relative to the second tier
construction,
- 25 3) ballasting the first tier construction toward
its deep draft floating state thereby to move
it into engagement with the second tier
construction,
- 30 4) securing the engaged constructions from lateral
relative movement,
- 35 5) and deballasting at least the second tier con-
struction adequately to render the combination
of the first and second tier constructions
positively buoyant and free floating,
- c. repeating in water of suitable depth the opera-
tions described in step b., as necessary, mutatis
mutandis, with each additional tier construction
proceeding downwardly through additional tier
constructions and with each combination of engaged
tier construction above each additional tier



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- 1 construction, thereby to fully assemble all tier
constructions of the offshore structure as a group,
- d. deballasting the group fully assembled tier
constructions to a draft less than the water depth
5 at the selected site,
- e. moving the group of assembled tier constructions
to the selected site,
- f. ballasting the group of assembled tier construc-
tions to sink into a condition of support by a
10 sea floor at the site, and
- g. further ballasting the tier constructions to
establish a desired effective mass of the group
of tier constructions.

15 66. The method according to claim 65 wherein the tier
constructions are each comprised of at least one modular
structural unit having height and length equal to the height
and length of the corresponding tier construction, each
modular structural unit for the upper tier construction
20 being provided in form operable as a submersible barge having
sufficient size and positive buoyancy to support in its
positively buoyant state the largest one of the modular
structural units of the additional tier constructions, and
including the further steps of

- 25 a. moving the said largest one modular structural
unit to the assembly location on an upper tier
construction modular structural unit,
- b. submerging the upper tier construction modular
structural unit to render said largest one
30 modular structural unit free floating,
- c. moving the floating said largest one modular
structural unit away from the submerged upper
tier unit, and
- d. deballasting the submerged upper tier unit to
35 render the same positively buoyant.



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1 67. The method according to claim 66 wherein each tier
construction is comprised of at least two modular structural
units of essentially equal height and length as tier subunits,
each tier subunit being floatable and controllably ballastable
5 between positively and negatively buoyant states, and includ-
ing the further step of

 connecting the subunits of each tier construction
together at the assembly location to define the
several tier constructions.

10

 68. The method according to claim 67 wherein the
positioning step described at step b.2) in claim 65, as
practiced according to the appropriate one of steps b.2)
and c. of claim 65, includes orienting the tier subunits
15 to be ballasted into engagement with a submerged tier
construction with their lengths disposed transversely of
the lengths of the subunits comprising the submerged tier
construction.

20

 69. The method according to claim 65 including the step
of placing over substantially the entire area of the upper
surface of each tier construction which is to be engaged at
its upper surface by another tier construction a layer of a
material which under load by said another tier construction
25 conforms inelastically to irregularities in the opposing
surfaces of the tier constructions upon engagement.



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1 70. The method according to claim 65 including the
steps of establishing the location on the assembled group
of tier constructions of the waterline thereof when the
group is supported by the sea floor at the selected site,
5 and attaching an ice resisting armor belt to the assembled
group at the waterline substantially around the pertinent
tier construction.

10 71. The method according to claim 65 including the
further steps of engaging with the sea floor at the
selected site in a fully submerged state a base assembly
having an upper surface sufficiently large to engage the
bottom surface, over the area thereof, of the assembled
group of tier constructions, the base assembly being
15 arranged to receive and support the said desired effective
mass and to distribute said mass over a larger area of the
sea floor.

20 72. The method according to claim 65 including the
further step of providing a desired operations facility
on the upper surface of the assembled group of tier
constructions.



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Fig. 1.

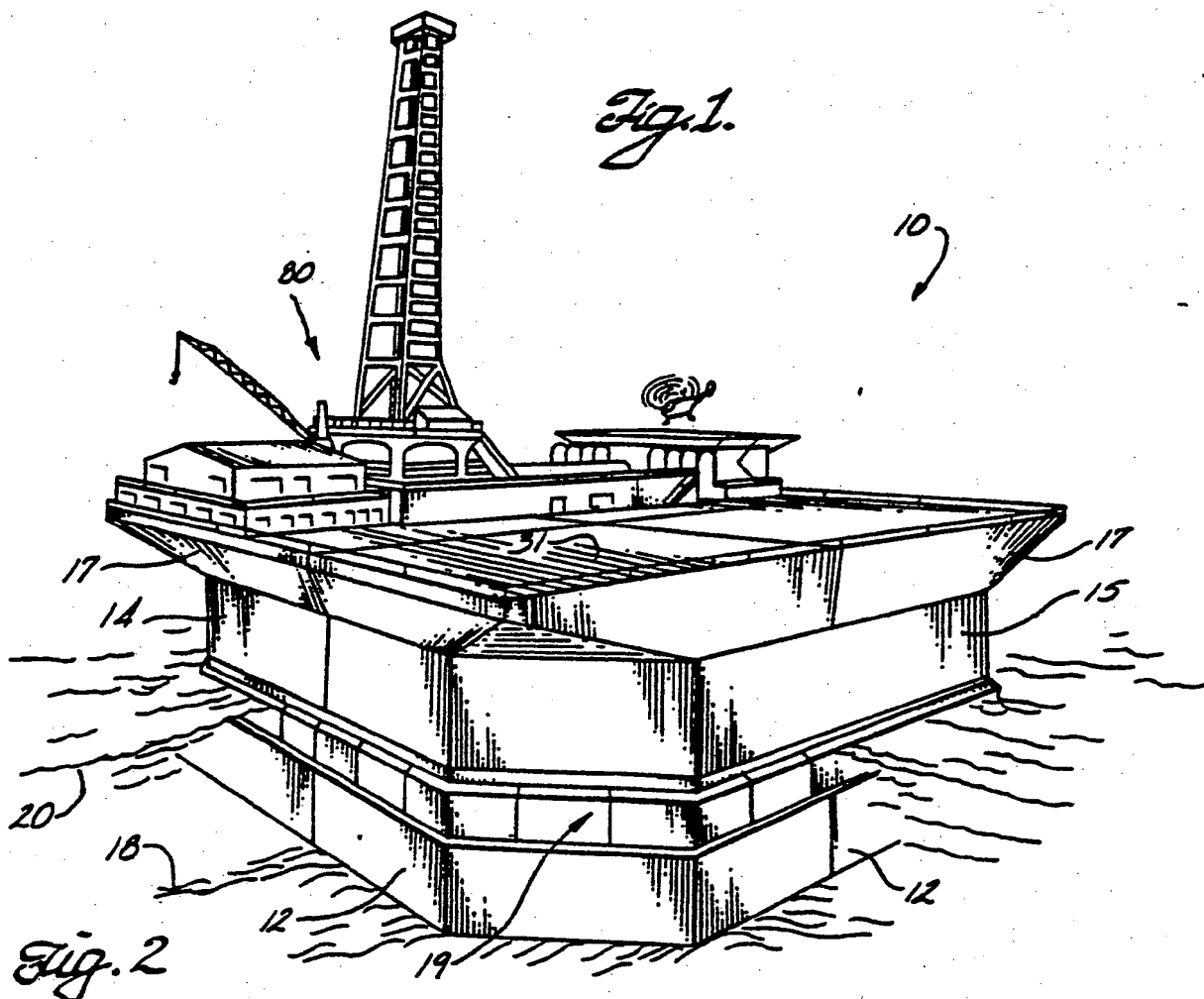
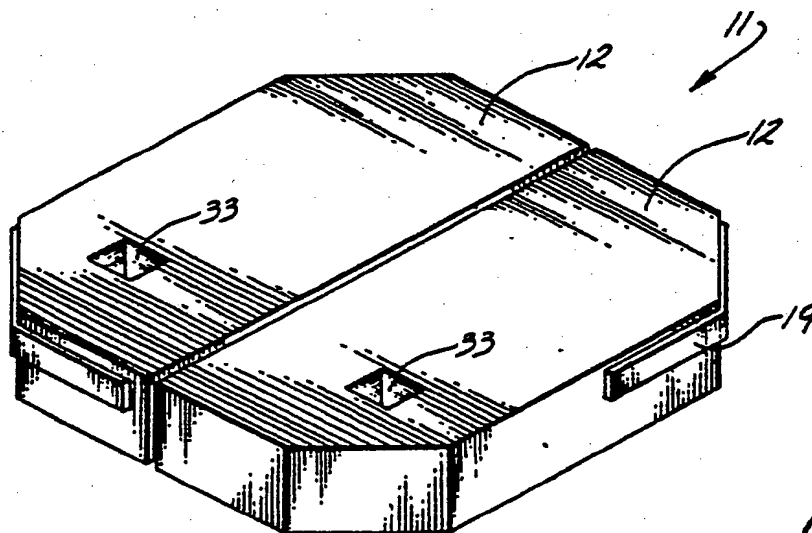
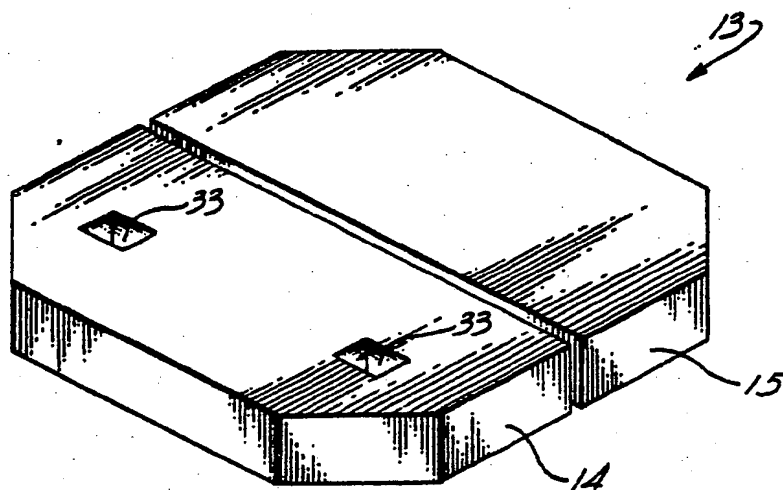
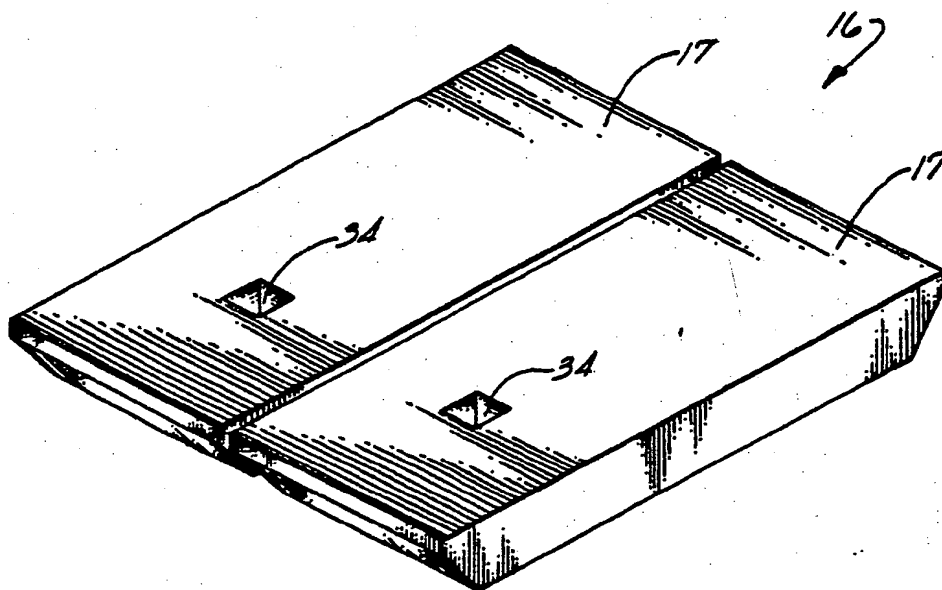


Fig. 2

<u>16</u> DECK UNITS (STEEL)	<div>21</div> <div>DSB</div> <div>17</div> <div>DSBR</div> <div>22</div> <div>IDU</div>
<u>11,13</u> BRICKS (CONCRETE)	<div>BB 44</div> <div>12</div> <div>BB 32</div> <div>14,15</div> <div>BB 17</div>
<u>19</u> ARMOR PANELS (CONCRETE)	<div>23</div> <div>AP28</div> <div>24</div> <div>AP14</div>
BASES	<div>25</div> <div>26</div> <div>27</div> <div>1MB</div> <div>28</div> <div>29</div>

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Fig.
3



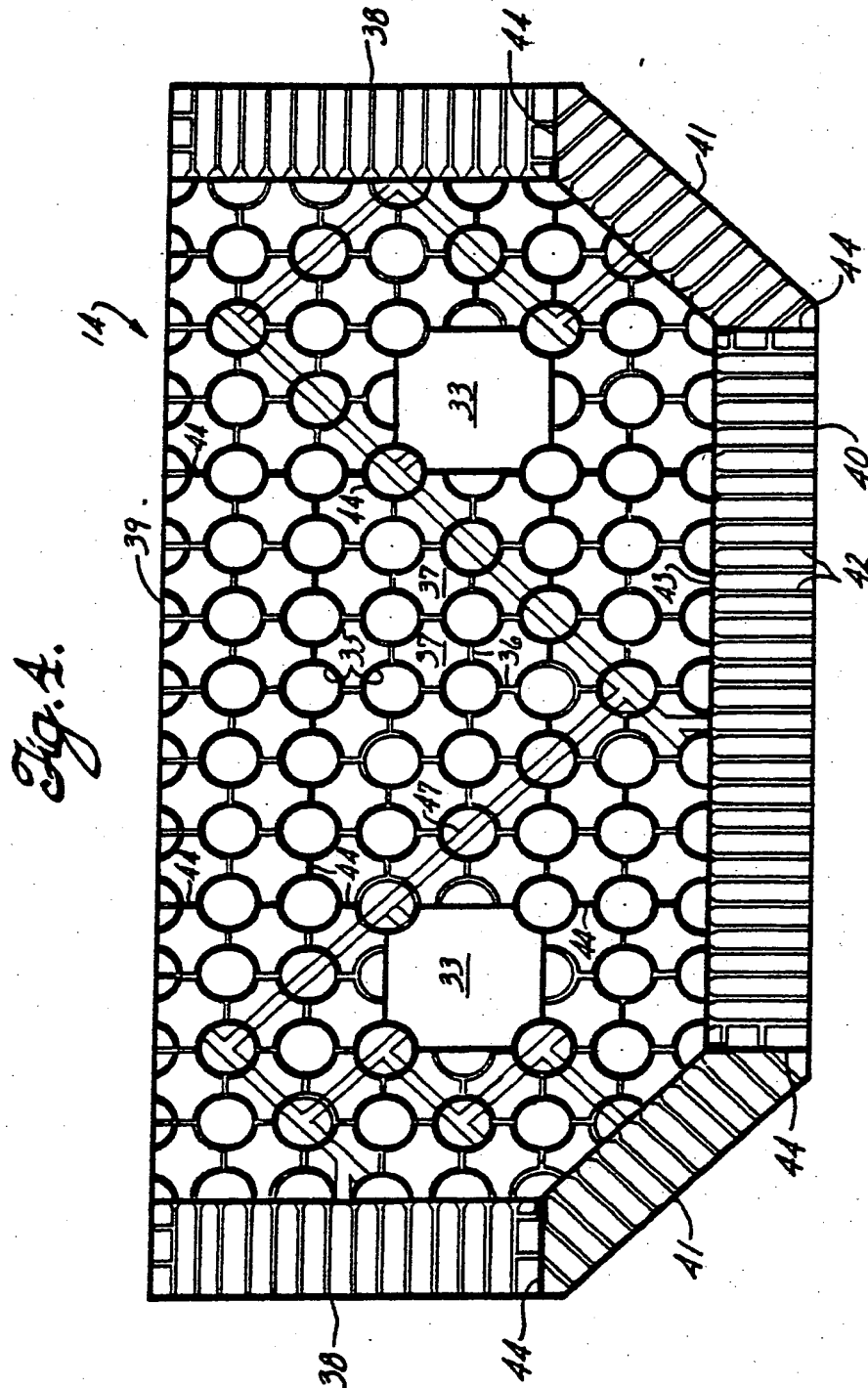
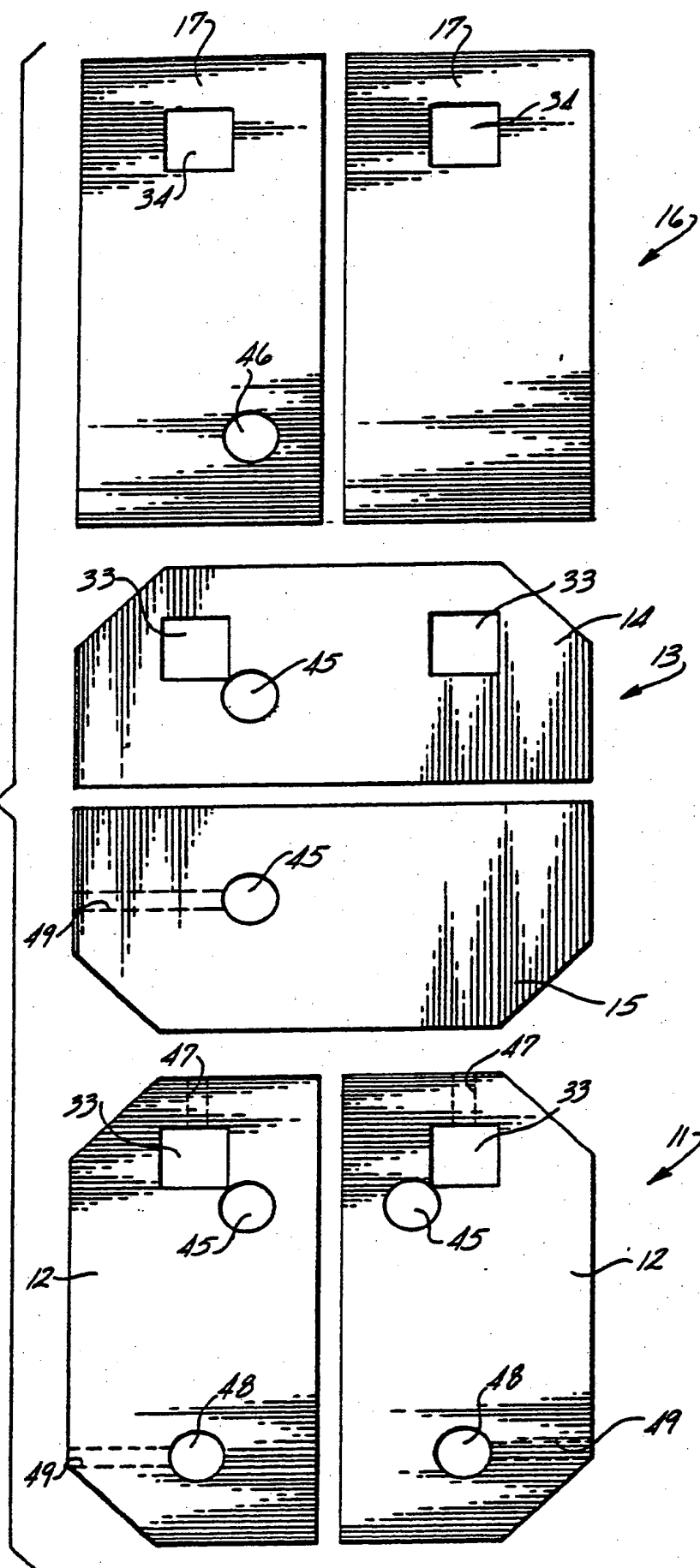
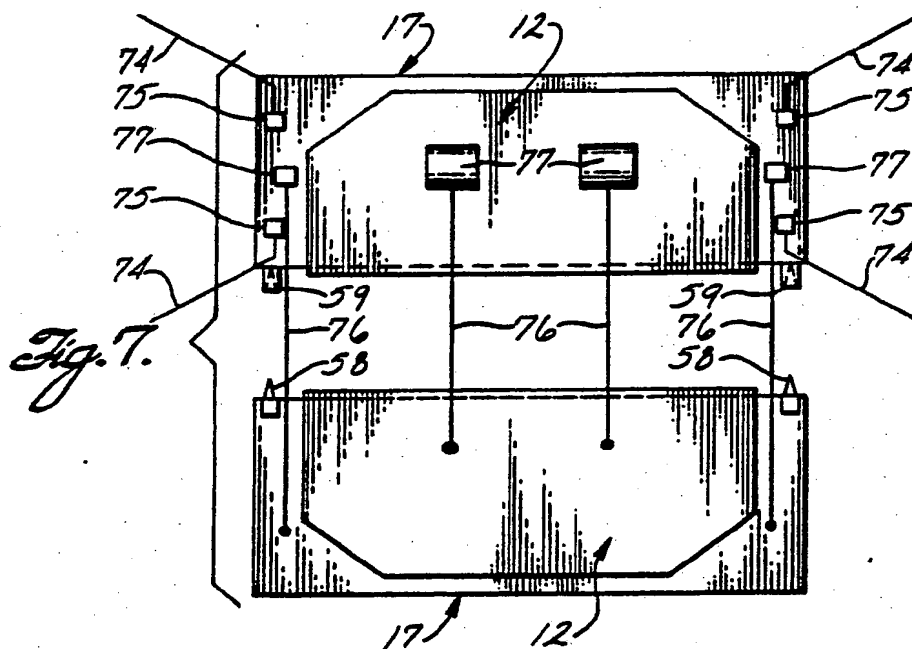
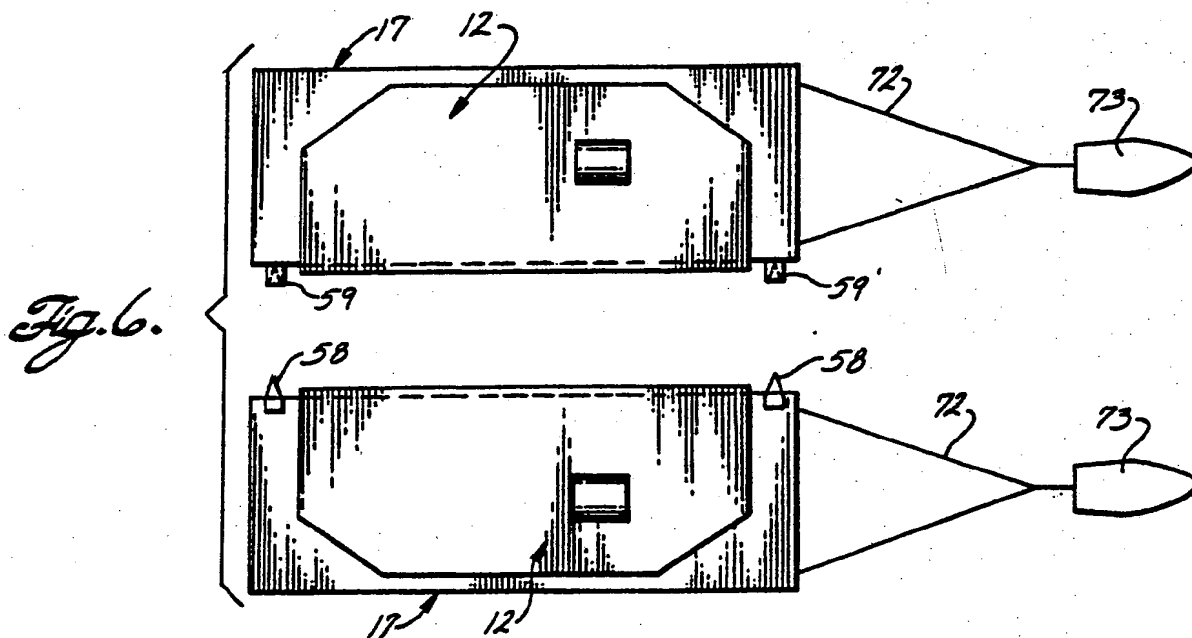


Fig. 5.



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Fig. 8.

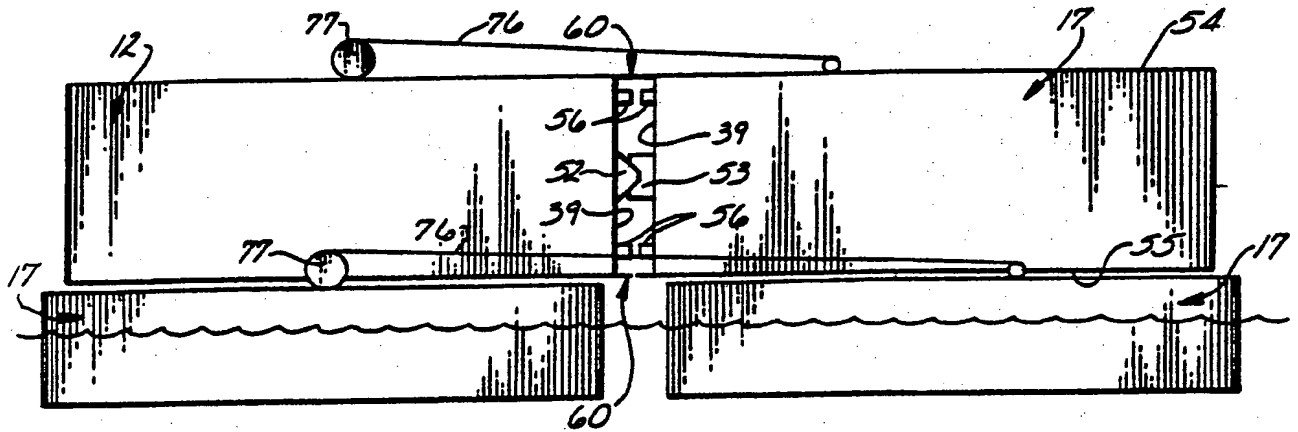


Fig. 9.

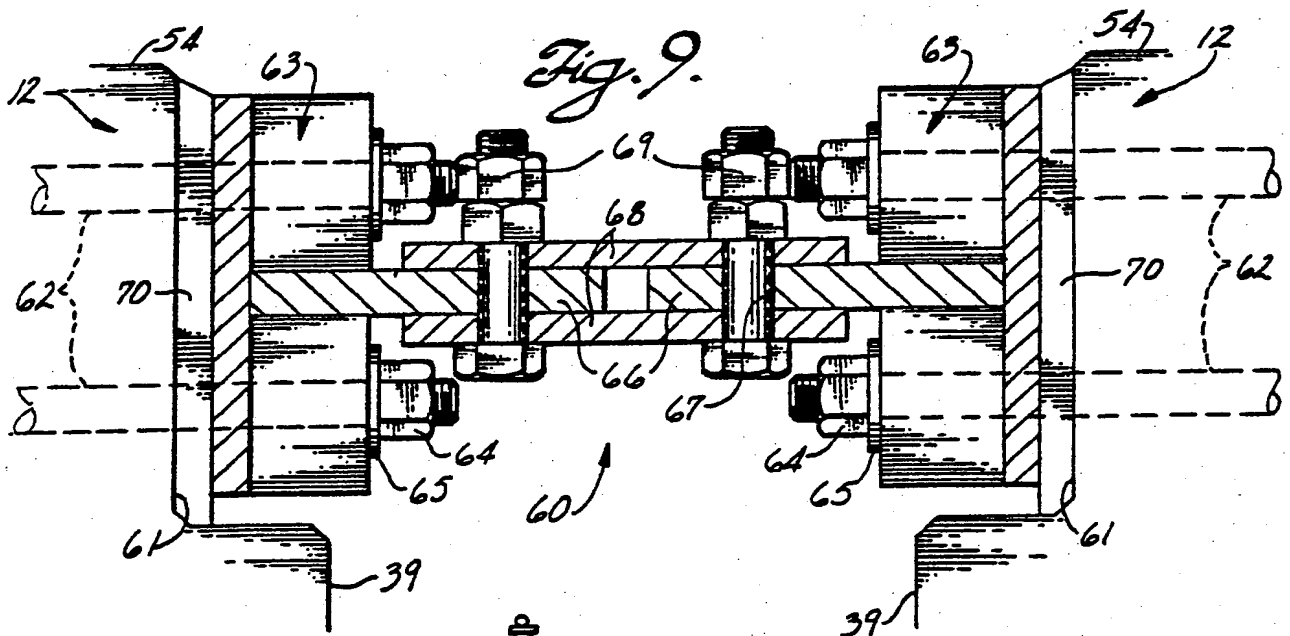
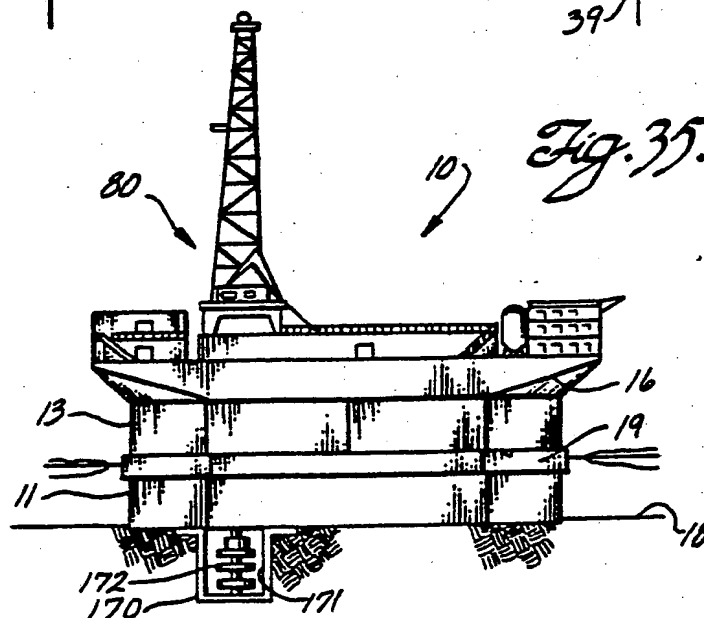


Fig. 35.



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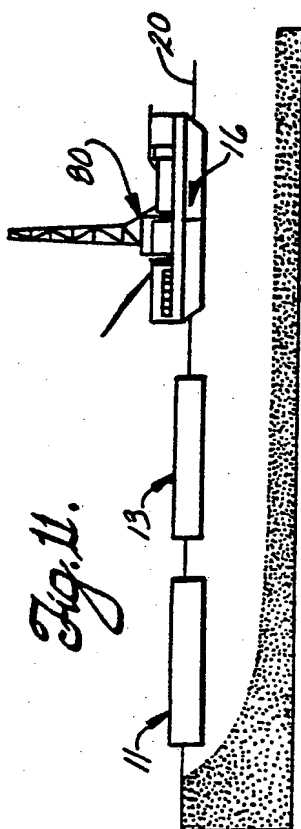


Fig. 10.

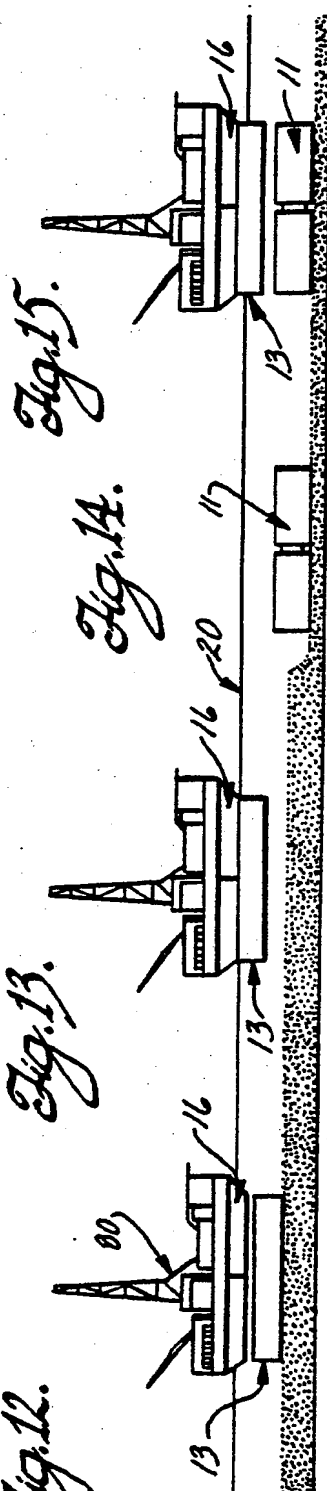


Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

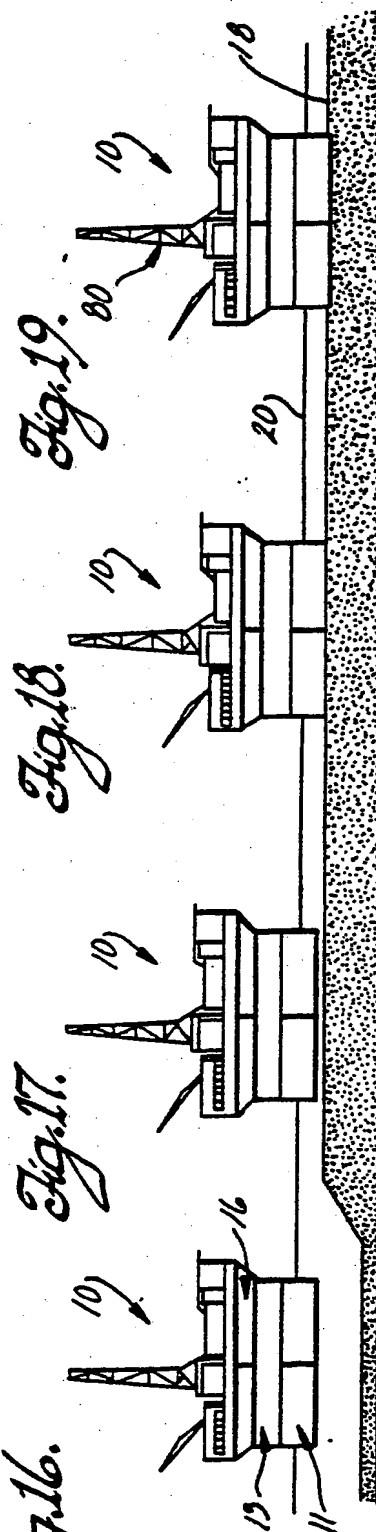


Fig. 16.

Fig. 17.

Fig. 18.

Fig. 19.

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Fig. 22

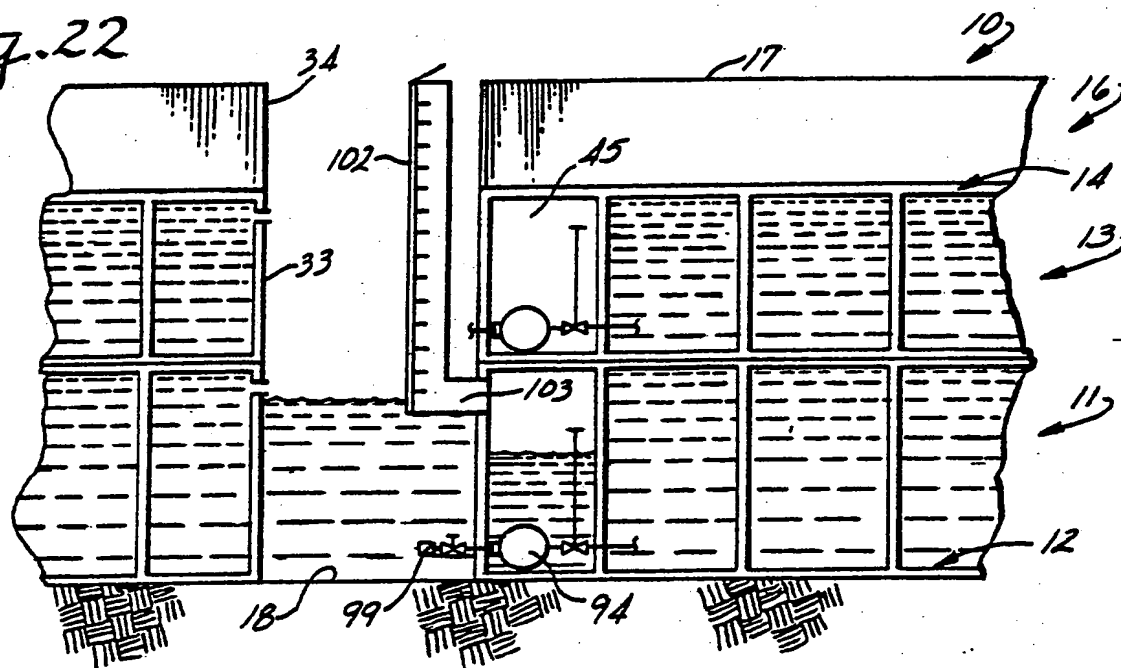
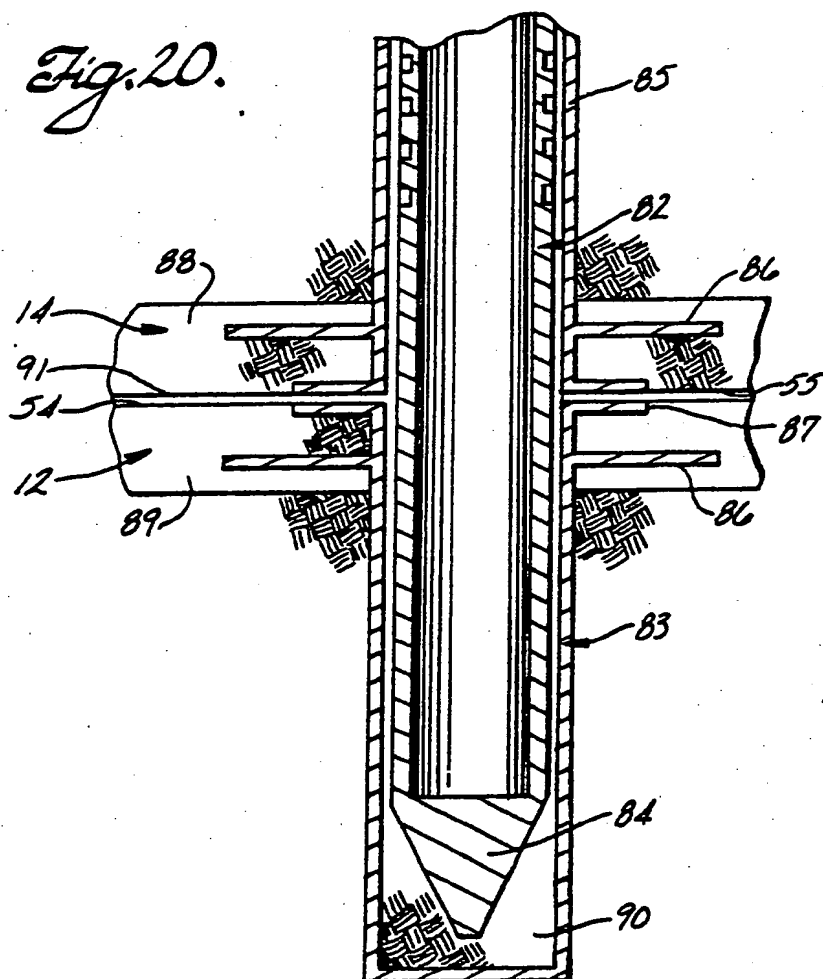
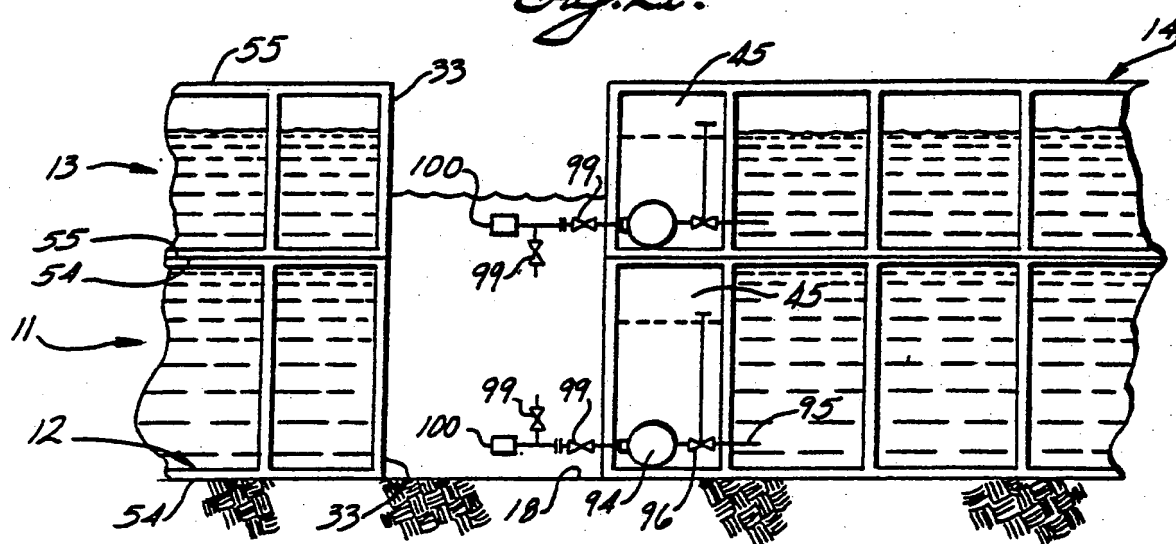
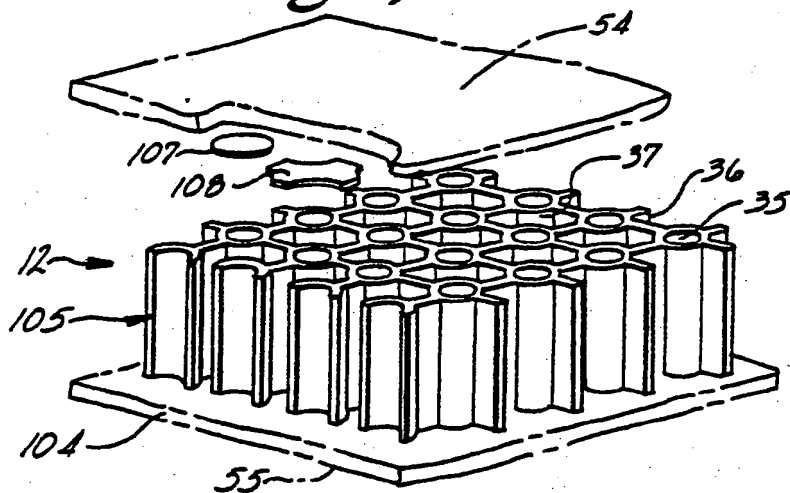
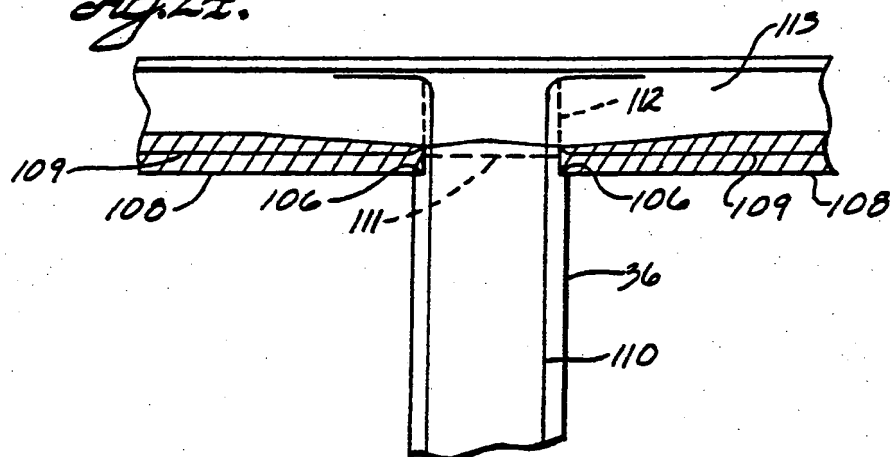


Fig. 20.



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Fig. 21.*Fig. 23.**Fig. 2A.*

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Fig. 25.

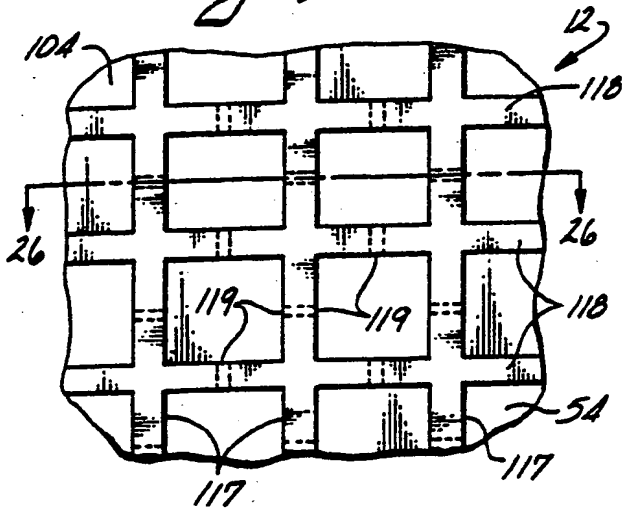


Fig. 26.

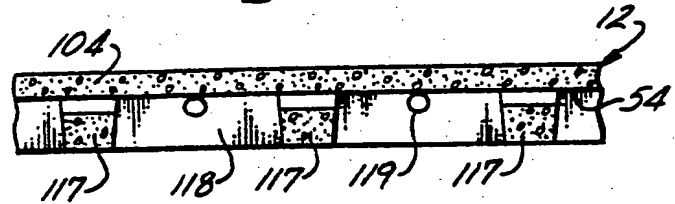


Fig. 27.

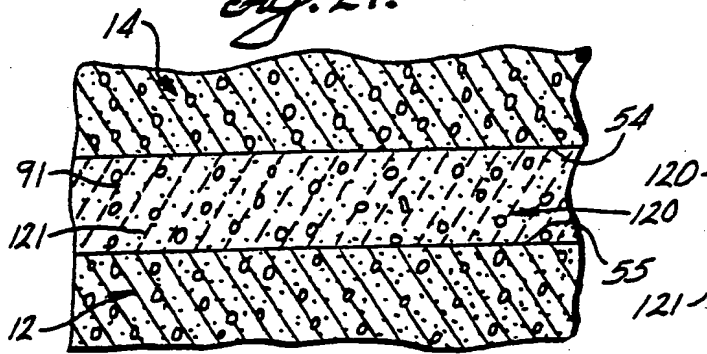


Fig. 28.

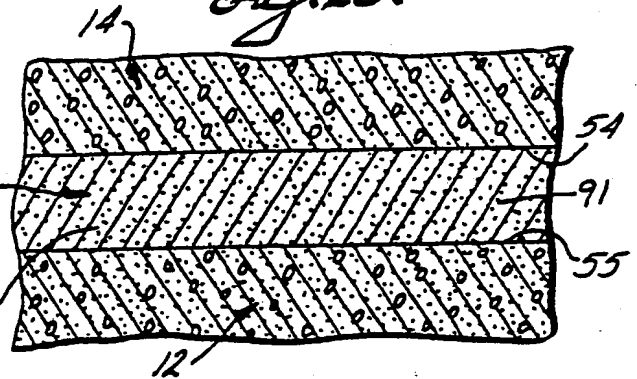


Fig. 29.

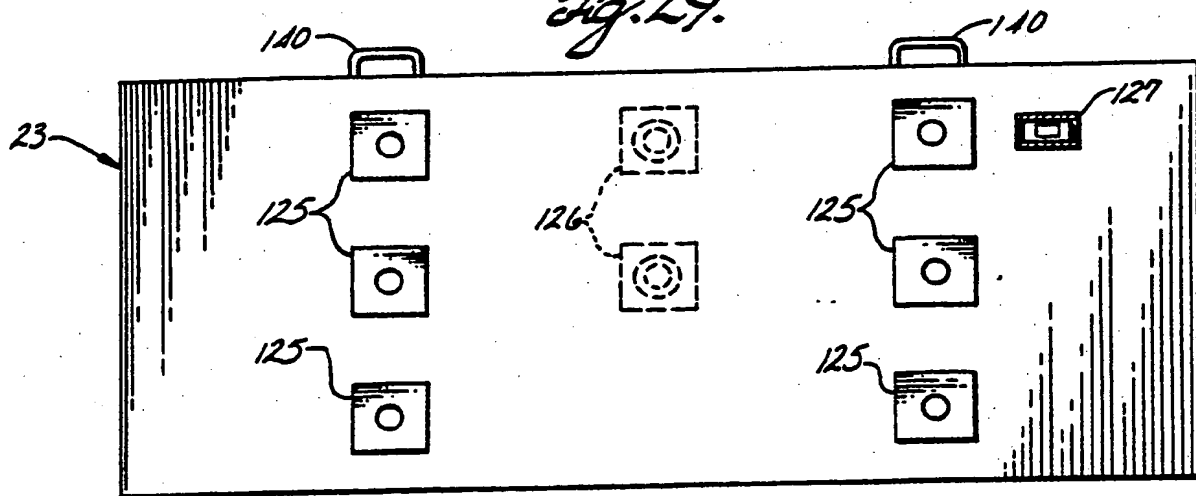
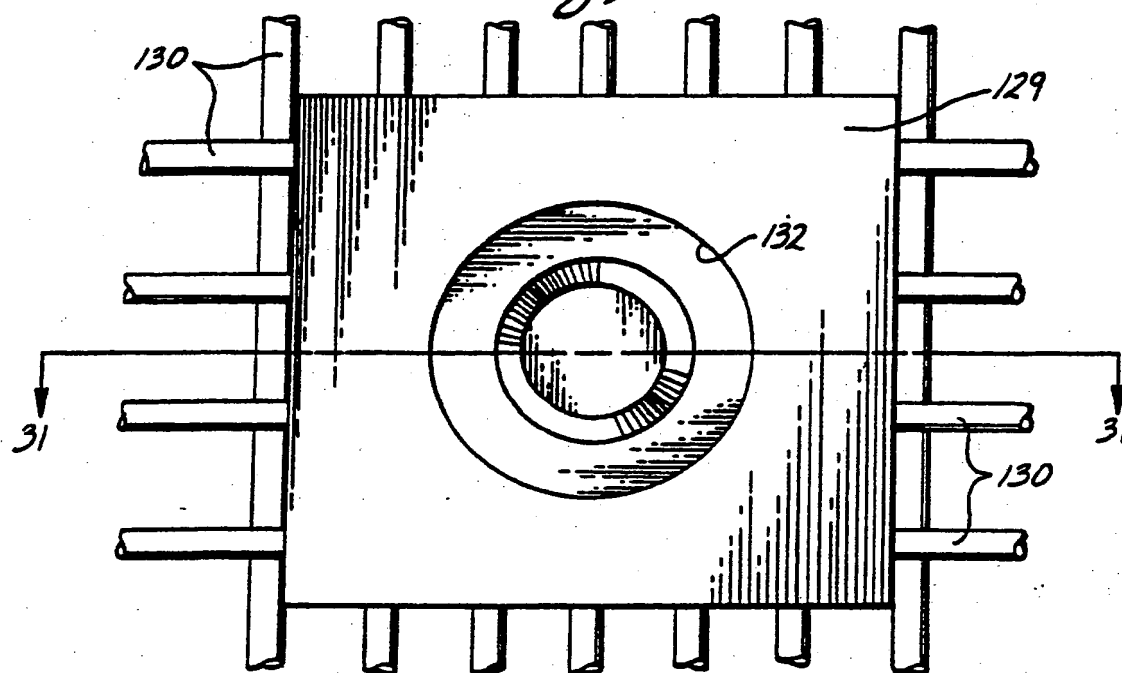
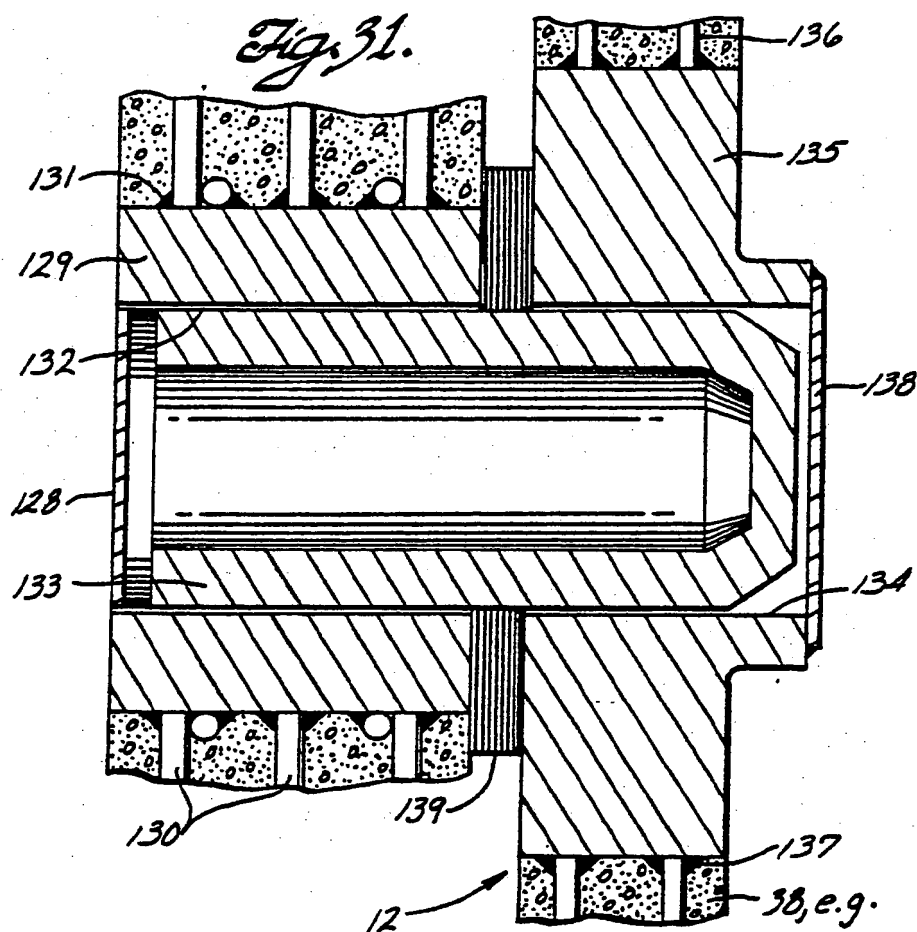
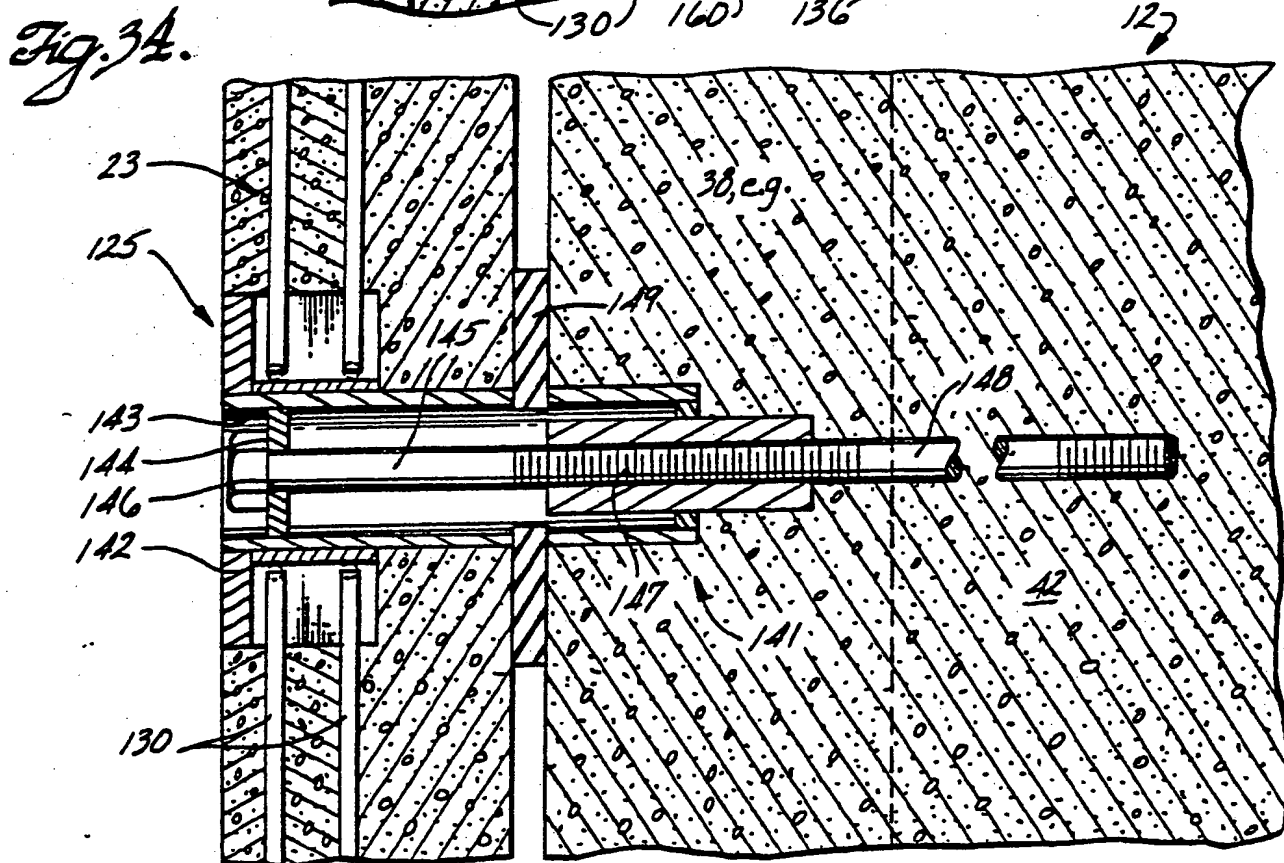
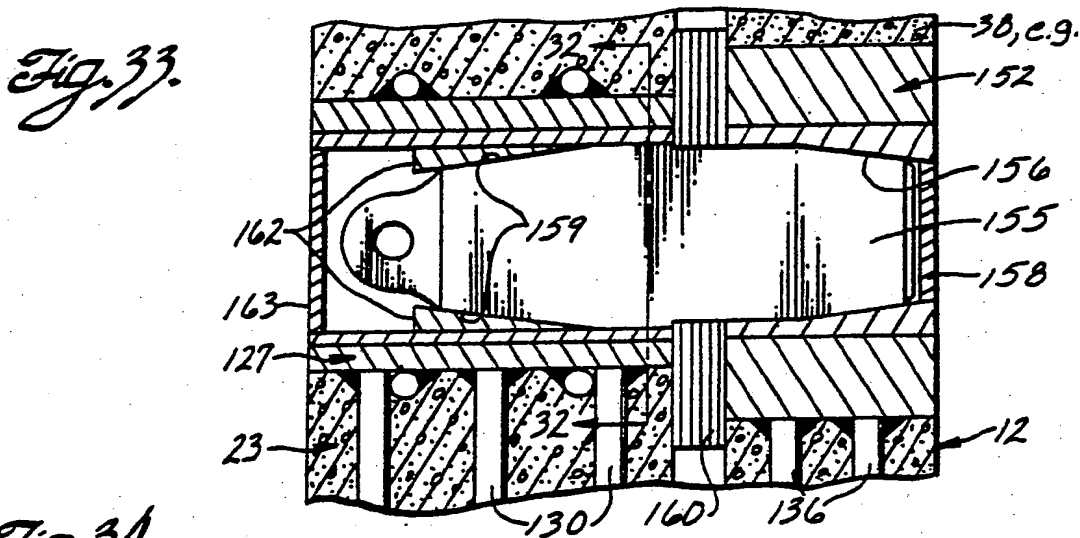
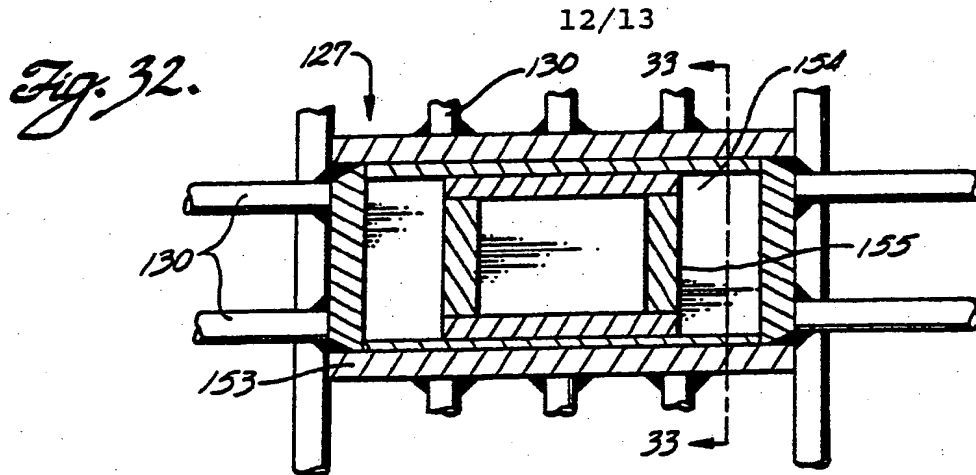
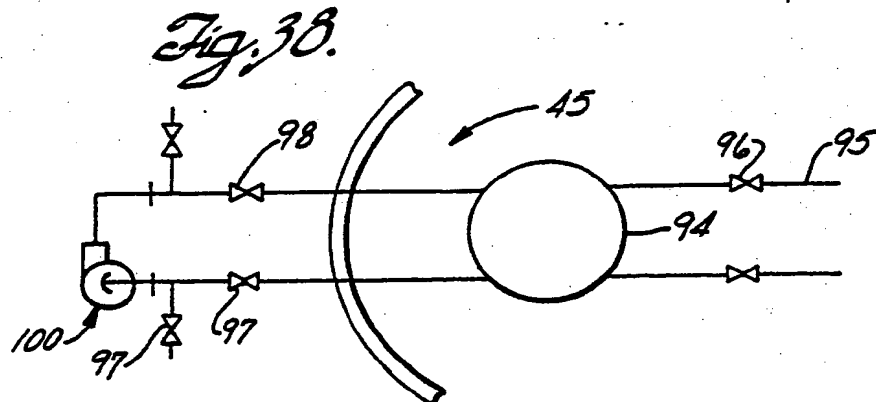
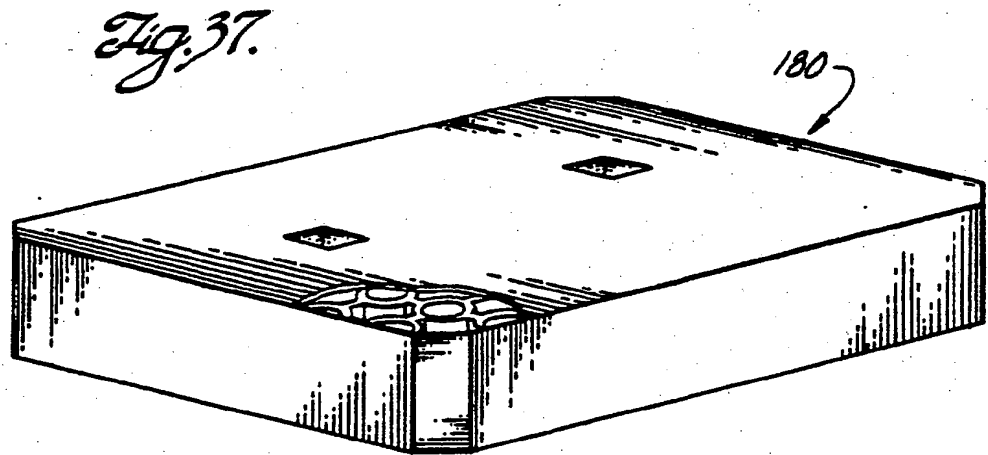
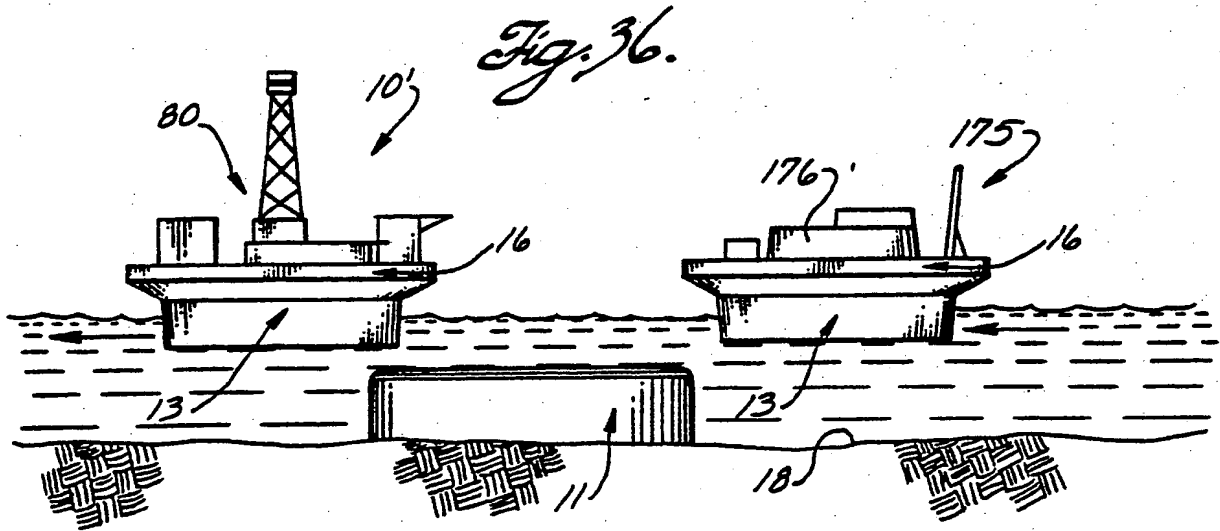


Fig. 30.*Fig. 31.*





INTERNATIONAL SEARCH REPORT

International Application No PCT/US83/01856

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) ³		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl. ³ E02B 17/02, E02D 23/02		
U.S. Cl. 405/203, 204, 217, 52/235		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁴		
Classification System	Classification Symbols	
U.S.	405/195, 203-209, 217, 60 52/235	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched ⁵		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ¹⁴		
Category [*]	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No. ¹⁸
Y	US, A, 3,698,198 (PHELPS) October 1972	1-13, 21-29 33-48, 53-58
Y	US, A, 4,155,671 (VOS) May 22, 1979	22, 23, 65-69 71 and 72
X	US, A, 4,314,776 (PALMER ET AL) February 9, 1982	1-18, 21-29 32-48, 53-58
A	US, A, 4,425,055 (TIEDEMANN) January 10, 1984	1-18, 21-29 32-48, 53-58
A	DT, A, 26 47 330 (JARRETT) August 4, 1977	1, 2
A	GB, A, 1,430,084 (HANSEN) March 31, 1976	1-8, 21-29 32-48, 53-58
Y	US, A, 2,528,089 (SIECKE ET AL) October 31, 1950	15-18
A	US, A, 3,708,987 (ROULET ET AL) January 9, 1973	19, 20
<p>[*] Special categories of cited documents: ¹⁵</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents; such combination being obvious to a person skilled in the art.</p> <p>"&" document member of the same patent family</p>		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search ¹		Date of Mailing of this International Search Report ²
February 28, 1984		01 MAR 1984
International Searching Authority ¹		Signature of Authorized Officer ²⁰
ISA/US		<i>Dennis L. Taylor</i> D. Taylor

Form PCT/ISA/210 (second sheet) (October 1981)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷	Relevant to Claim No ¹⁸
Y	US, A, 2,892,314 (HORNSBY ET AL) June 30, June 30, 1959	33-35
Y	US, E, RE 30,823 (GUY ET AL) December 15, 1981	15-18
Y	US, A, 3,952,527 (VINIERATOS ET AL) April 27, 1976	7
Y	US, A, 875,699 (DUMAIS) January 7, 1908	25-29, 32-42 43,54,55,57 59-64,70
Y	US, A, 3,209,544 (BORRMANN) October 5, 1965	25-29,32,42 43,54,55,57 59-64,70
A	US, A, 3,465,996 (E. VON WEDEL) september 9, 1969	25, 54
A	US, A, 3,784,357 (MURAOKA) January 8, 1974	25, 54
A	US, A, 3,972,199 (HUDSON ET AL) August 3, 1976	25, 54
A	US, A, 4,202,647 (LAMY) May 13, 1980	25, 54
A	GB, A, 2,058,181 (WESLEY) April 8, 1981	25, 54